Peer Review Draft

STAFF REPORT
TO SUPPORT THE
TECHNICAL SEDIMENT
TOTAL MAXIMUM DAILY LOAD
FOR THE
UPPER ELK RIVER

March 4, 2013

State of California
North Coast Regional Water Quality Control Board
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Regional Water Board staff recognizes that the Peer Review Draft Staff Report to Support the Technical Sediment Total Maximum Daily Load for the Upper Elk River (Peer Review Draft Staff Report) contains typographical and editorial errors and regrets any difficulty these may pose to the reader. However, in order to ensure complete transparency, staff has elected to release the Peer Review Draft Staff Report just as was sent to the peer reviewers. This errata sheet identifies and corrects editorial errors associated with citations, however does not attempt to identify every editorial error. In preparation for its future release as a public review draft of the Technical TMDL Staff Report, staff will clarify and improve upon the Peer Review Draft Staff Report in several areas including making necessary editorial corrections.

Errata

Pg iii	Table of Contents, Chapter 6 should refer to Section 6.1 Water Quality Objectives for Sediment and Section 6.2 Hillslope and Instream Target Conditions
Pg ix	List of Appendices, Appendix 4D should cite (PWA, 2008a)
Pg ix	List of Appendices, Appendix 4E should cite (PWA, 2006b)
Pg ix	List of Appendices, Appendix 3A should cite (RCAA NRS, 2003)
Pg 2-10	Citation for (Benda 2003a) should read: (Martin and Benda, 2001)
Pg 2-15	Citation for (Johnson, 1988) should read: (Johnson, 1998). a
Pg 4-3	Footnote 46 citation for (Palco 2005), should read (Palco 2005d)
Pg 4-3	Bullet 9 citation for (PWA 2006) should read (PWA 2006a)
Pg 4-3	Bullet 13 citation for (PWA 2006) should read (PWA 2008a)
Pg 4-3	Bullet 13 citation for (PWA 2008) should read (PWA 2006b)
Pg 4-3	Bullet 16 Citation (Palco 2006 & 2007) should read (Palco, 2007 & 2008)
Pg 4-13	Citation for (PWA 2006) should be (PWA 2008b)
Pg 4-19	Citation (Palco, 2004) should read *Elk River and Salmon Creek Watershed Analysis* (Palco, 2004a).
Pg 4-34	Citation for (Stillwater 2005) should read (Stillwater 2007)
Pg 4-36	Citation for PWA (2006) should read PWA (2008a)
Pg 4-36	Caption for Figure 4.10 should cite (PWA 2006b)
Pg 4-37	Caption for Table 4.12 should cite (PWA 2006b)
Pg 4-37	Citation for (Palco 2004) should read (Palco 2004a)
Pg 4.42	Citation for (Palco, 2005) should read (Palco, 2005c)
Pg 4-44	Citation for PWA (2006) should read PWA (2006a)
Pg 4-44	Footnote 72 should read (PWA 2006a)
Pg 4-44	Footnote 74 citation should read: Completed Annual Summary Report for South Fork Elk River (GDRC 2008, 2009 and 2010).
Pg 4-45	Footnote 74 citation should read (GDRC 2008, 2009 & 2010)
Pg 4-45	Citation for PWA (2006) should read PWA (2006b)
Pg 4-45	Footnote 75 citation should read (PWA, 2000)
Pg 4-48	Citation in Table 4.17 for PWA (2001) should read PWA (2005d)
Pg 4-50	Table 4.18 citation for (Palco 2007) should read (Palco 2007a)
Pg 4-50	Citation for PWA (2005 a & b) should read: PWA (2005 b & c)
Pg 4-56	Citation for (PALCO 2007) should read: (Palco 2007b)
Pg 4-60	Citation for (Palco 2004) should read (Palco 2004a)

Pg 4-60 Citation for (Palco 2005) should read (Palco 2005a)
Pg 4-60 Footnote 87 citation for (Palco 2004) should read (Palco 2005a)
Pg 4-68 Citatation for Palco WA (2004) should read: Palco WA (2004a)
Pg 4-68 Citation for (Palco, 2004 citing Elliot et al. 2000) should read: (Palco, 2004a)
Pg 4-69 Citation for (HRC, 2013) should read (HRC, 2012b)
Pg 5-5 Caption for Table 5.5.1 should read Table 5.1
Pg 5-11 Table 5.3 entry corresponding to Total Middle Reach Instream Deposit Loading should read 1,412 $yd^3/mi^2/yr$
Pg 6-10 Footnote 96 should read Order No. R1-2008-0100
Pg 6-17 Citation for (EPA 2001) should read: (USEPA, 2001b)
Pg 7-2 Footnote 103 should read: Habitat Conservation Plan for Pacific Lumber Company Lands. (USFWS and Calfire,1999).
Pg 7-6 First sentence of last paragraph refers to *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program* (NPS Policy) should cite (State Water Resources Control Board, 2004)
Pg 7-7 Footnote 106 should read (USEPA, 2000)

Upper Elk TMDL Development Team

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List of Abbreviations

303(d) List *Clean Water Act Section 303(d) List of Impaired Waterbodies*
AHCP Aquatic Habitat Conservation Plan
Basin Plan *Water Quality Control Plan for the North Coast Region* (May, 2011)
BLM Bureau of Land Management
BMP Best management practice
Cal Fire California Department of Forestry and Fire Protection (formerly CDF)
CAO Cleanup and Abatement Order
CDF California Department of Forestry and Fire Protection (now Cal Fire)
CDFG California Department of Fish and Game (now California Department of Fish and Wildlife)
CDFW California Department of Fish and Wildlife (formerly California Department of Fish and Game)
CEQA California Environmental Quality Act
cfs cubic feet per second
CSG California Geologic Survey
CWA Clean Water Act
DEM Digital Elevation Model
DSLED Deep-seated landslide and earthflow detection model
FEMA Federal Emergency Management Agency
FPR Forest Practice Regulations
GIS Geographic Information System
GDRC Green Diamond Resources Company (formerly Simpson Resource Company)
HBCSD Humboldt Bay Community Services District
HCP Habitat Conservation Plan
HRC Humboldt Redwood Company
HST Hydrodynamic sediment transport model
HY Hydrologic year
ISRP Independent Scientific Review Panel
LA Nonpoint sources load allocations
LiDAR Light Detection and Ranging
Maxxam Maxxam Corporation
mi^2 square mile
mm millimeters
MRC Mendocino Redwood Company
MRP Monitoring and Reporting Report
NB Load allocation to account for natural background pollutant loads
NHE Northern Hydrologic Engineering
NPDES National Pollution Discharge and Elimination System
NPS Nonpoint source

NPS Policy *Policy for the Implementation and Enforcement of the Nonpoint Source Pollution Control Program* (2004)
NRS Natural Resource Services
NOAA National Oceanic and Atmospheric Agency
NTMP Non-Industrial Timber Management Plan
NTU Nephelometric turbidity units
Palco Pacific Lumber Company, Scotia Pacific Corporation, and Salmon Creek Corporation (collectively referred to as Palco)
Porter Cologne Porter-Cologne Water Quality Control Act
PWA Pacific Watershed Associates
RCAA Redwood Community Action Agency
Regional Water Board North Coast Regional Water Quality Control Board
Resolution 68-16 *Statement of Policy with Respect to Maintaining High Quality Waters in California* (1968)
SEV Severity of Ill Effects Index
SHALSTAB
Staff Report *Staff Report to Support the Technical Sediment Total Maximum Daily Load for the Upper Elk River* (2013)
State Water Board State Water Resources Control Board
SYP Sustain Yield Plan
THP Timber Harvest Plan
TMDL Total Maximum Daily Load
TTS Turbidity threshold sampling
USEPA United States Environmental Protection Agency
USGS United States Geologic Survey
Upper Elk TMDL *Technical Sediment Total Maximum Daily Load for the Upper Elk River*
WA Watershed Analysis
Waiver Waiver of Waste Discharge Requirements
WDR Waste Discharge Requirements
WEPP Water and Erosion Prediction Program
WLA Point source load allocations
WWDR Watershed-wide Waste Discharge Requirements

Summary of the Upper Elk River Sediment TMDL Technical Analysis and Implementation Framework

Introduction

Elk River is a 58.2 mi^2 watershed located in the coastal temperate rain forest of Humboldt County in northern California. , which enters Humboldt Bay just south of the City of Eureka. In 1998, the entire Elk River watershed was identified as impaired due to excessive sedimentation and was placed on the Impaired Waters List as required under section 303(d) of the Clean Water Act.

To facilitate the focus on the primary sediment sources and impairments, staff delineated the watershed into three waterbodies including Upper Elk River (44.2 $mi^{2)}$, Lower Elk River (14.3 mi^2) and Upper Little South Fork Elk River (3.6 mi^2). This staff report provides the basis for the Upper Elk River TMDL and focuses on the impacts to beneficial uses due to excessive sediment discharges from the Upper Elk River subbasin, which is primarily impacted by industrial timber harvesting. Staff proposes the impairments in Lower Elk River be addressed via regulatory programs under development that would address stormwater flows from the City of Eureka and runoff from agricultural lands. The Upper Little South Fork Elk River is contained within the Headwaters Forest Reserve, is used as a reference stream in the Upper Elk TMDL analyses and, currently achieves water quality standards and beneficial use protection and is recommended for delisting from the Impaired Waters List.

A TMDL is required to address beneficial uses and water quality objectives contained in the *Water Quality Control Plan for the North Coast Region*, adopted by the North Coast Regional Water Quality Control Board and often referred to as the Basin Plan. The TMDL includes analyses related to municipal water supply (MUN); agricultural supply (AGR); water contact recreation (REC-1); non-contact water recreation (REC-2); cold freshwater habitat (COLD); migration of aquatic organisms (MIGR); and spawning, reproduction, and/or early development (SPWN). The analyses address sediment-related water quality objectives designed to protect these uses. The sediment-relate objectives include objectives for: suspended material; settleable material; suspended sediment load; and turbidity.

Watershed Overview

The Upper Elk River subbasin is underlain by highly erodible geology which produces an abundance of fine sediment. The slopes of this subbasin are relatively steep and unstable. The natural vegetative cover of the redwood forest community serves to stabilize the steep slopes with a network of fine roots. It builds soil with slowly decomposing duff, varied microorganisms, and a rich understory. The canopy intercepts rainfall and acts as storage for water through evapotranspiration. The watershed has supported commercial timber operations since the late 1800s. But, intensive clear-cut logging beginning in 1986, followed in the 1990s with multiple years of larger-than-average rainfall, have resulted in widespread landsliding and erosion, as described in the Sediment Source Analysis.

In 1999, the Headwaters Agreement was brokered between the federal and state governments and Palco, to establish an old growth redwood preserve to be managed by the U.S. Bureau of Land Management (BLM). The Headwaters Forest Reserve is located in the South Fork Elk River, including 3,088 acres of old growth redwoods and 4,384 acres of previously harvested timberlands. In 2007, Palco filed for bankruptcy and in 2008 Humboldt Redwood Company (HRC) took over ownership and management of the former Palco timberlands. The current predominant landowners/land managers in the Upper Elk River subbasin include HRC, Green Diamond Resource Company (GDRC) and BLM. HRC and GDRC both manage their lands for industrial timber harvesting, with HRC employing silviculture prescriptions associated with uneven-age management (i.e., selection and group selection) and GDRC relying on primarily even-aged management (i.e., clear-cutting). BLM manages the Headwaters Forest Reserve for non-contact water recreation and conservation. All three of the primary landowners have management plans and permits which address several factors affecting management-related sediment loading

Problem Statement

Qualitative and quantitative measures confirm the impairment of domestic and agricultural water supplies, recreation, cold water aquatic habitat, and the presence of nuisance flooding. Historic and current discharges of fine sediment are confirmed as sources of these impairments.

Residential use in the Upper Elk River is concentrated in the lower portions of subbasin within the North Fork, South Fork and mainstem portions of the subbasin. Many of these residents have historically relied on surface water for domestic and agricultural water supplies. But, coincident with the period of accelerated harvesting, the Regional Water Board began receiving complaints from residents that their water supplies were being degraded by elevated turbidity, even during minor storms, and increased silt in their drinking water and sediment deposition accumulating around their water intakes. A comparison of turbidity levels from two managed subbasins and a reference subbasin confirm that timber harvest activities in the Upper Elk River subbasin have resulted in a vast increase in turbidity levels downstream. Similarly, stream channel cross sections measured from 1997 to 2011 in the upper mainstem, lower North Fork and lower South Fork Elk River confirm a significant reduction in cross-sectional area during that period, including a reduction in pool depths.

Elevated turbidly damages water intakes, storage tanks, plumbing, water heaters, and other system components. It promotes bacterial growths which lead to unpalatable tastes and odors. And, it reduces the effectiveness of filters and disinfection, making water unsafe for drinking. Further, the depth of the pools formerly used to place water intakes, have now become so reduced as to make water withdrawal difficult. HRC has provided replacement water systems for several residents in recognition of their responsibility as current owners of former Palco lands.

In portions of Upper Elk River, overbank flooding occurs several times per year, affecting roads, fields, homes, and access to services. The cross- sectional area of the stream channel has been significantly reduced by deposits of fine sediment. Evaluation of cross-section data indicates there are over 280,000 yd^3 of instream stored sediment in the lower North Fork, nearly 100,000 yd^3 in the lower South Fork, and nearly 260,000 yd^3 in the upper Mainstem. The fine sediment deposits in the storage reaches of Upper Elk have become rooted in place by the encroachment of vegetation which further serves to slow down winter flood waters, causing them to spill over their banks at elevated frequency and magnitude. In 2004, 64 Elk River residents petitioned the Regional Water Board to require Palco to dredge the stored sediment; but the petition was denied on the basis that dredging might cause additional, unforeseen environmental damage. The Regional Water Board required a feasibility study, managed by a viable third party prior to initiating such an effort. In 2012, the Regional Water Board approved the *Elk River Recovery Assessment,* a study of the hydrodynamic processes in the affected reaches and modeling of the efficacy of various sediment remediation scenarios for restoring hydrologic function.

Recreational uses in the Upper Elk River watershed include: swimming, wading, fishing, boating, hiking, aesthetic enjoyment and others. Uses include both contact and non-contact with water. Impacts to recreation have been evaluated qualitatively and include: silty substrate unpleasant for wading, reduced stream depth impacting swimming and boating, anaerobic conditions producing unpleasant odors, and excessive aquatic vegetation growth during the summer.

Salmonids are identified in North Coast watersheds as the most sensitive of the native cold water aquatic organisms. They require clear, cold, well-oxygenated water; unimpaired migratory access to spawning grounds; clean, un-embedded gravels for spawning; and food, pools, and places to hide from predators for juvenile rearing. Analysis of bulk sediment samples indicates that the percent of fine grained sediment (<0.85 mm) far exceeds the numeric target for salmonid spawning of ≤ 14% (see Chapter 6 – Numeric Targets). A residual pool depth of at least 3 feet is necessary to provide adequate salmonid rearing space and protection from predators; residual pools depths substantially less than required.

Newcombe and Jensen (1996) developed a Severity of Ill Effects Index describing the effects associated with excess suspended sediment. Data analyzed from 9 Upper Elk River monitoring stations from 2003 to 2007 indicate the potential for a suite of sublethal effects ranging from 0-90% of the time. Sublethal effects include reduction in feeding, increased respiration, and habitat degradation.

Sediment Source Analysis

The sediment source analysis quantifies the timing and magnitude of past sediment loading associated with both natural and management-related hillslope sediment sources for nonpoint sources. There are no point sources of sediment discharge in the Upper Elk River subbasin.

There is an enormous inventory of sediment source and delivery data for the Upper Elk River subbasin, in part due to the stricter regulatory controls necessary as a result of the unprecedented increases in timber harvest activities during the late 1980s and 1990s and the resulting environmental impacts. The source analysis is data rich and is informed by sediment data collection and mapping efforts by a wide spread of professionals associated with agencies, timber companies, private consultants, and research institutions. Site-specific sediment inventory data were provided by Upper Elk River landowners and evaluated at a subbasin scale. If site-specific data were unavailable, loadings were developed based upon field-surveys in three study sub-basins located in in Upper Elk River.

Due to the volume and variety of data, the Sediment Source Analysis (Chapter 4) includes details, particularly for management-related sediment delivery, not often seen in similar TMDLs. The estimate of management-related sediment delivery is given for individual time periods from 1955 through 2011. The estimate of natural sediment delivery is averaged over the entire 56 year period. A variety of analytical approaches are used to estimate natural and management-related sediment loads, including literature values, field surveys in study subbasins in Upper Elk River and nearby Freshwater Creek including a reference area of Headwaters Forest Reserve, aerial photographs, GIS mapping, land use history, erosion monitoring conducted in Elk River, and application of erosion models. A channel initiation study in Upper Elk River informed estimates of the natural and management-related drainage densities over time. Analyses indicate that the natural drainage network incised headward as a result of management activities and the current drainage density is estimated to be three times greater than is naturally occurring in Upper Elk.

Natural sediment sources identified and quantified include streambank erosion, streamside landslides, shallow hillslope slides and deep-seated landslides. The long-term average loading from natural sources (1955-2011) is estimated to be 68 $yd^3/mi^2/yr$.

Management activities, including timber harvesting, road construction and reconstruction and restoration have affected the creation of sediment sources. The sediment sources affected by management activities that are identified and quantified in Upper Elk River sediment source analysis include:

- Low order channel incision (headward scour).
- Stream bank erosion.
- Road-related shallow hillslope landslides.
- Open-slope shallow hillslope landslides.
- Small streamside landslides.
- Management-related sediment discharge sites (e.g. gullies and stream crossing erosion features).

- Post-treatment discharge sites (e.g. erosion following correction of management sediment discharge sites).
- Skid trail features (e.g. diverted watercourses, compacted soil).
- Road surface erosion.
- Harvest (in-unit) surface erosion.

Prominent in this analysis is the importance of streamside landslides, open slope shallow landslides, road-related shallow landslides, and road surface erosion as sources of sediment from timber harvest operations. Management-related loading was estimated for several analysis time periods including 1955-1966, 1967-1975, 1975-1987, 1988-1997, 1998-2000, 2001-2003, and 2004-2011. Staff had access to different data for the 2004-2011 time period and as such results are presented differently than the other time periods.

Figure 1 shows the results of the sediment source analysis. The long-term average management-related loading is estimated to be 976 $yd^3/mi^2/yr$ (approximately 1000% of natural loading). The largest management-related loading is associated with the 1988-1997 time period which coincides with accelerated harvested and road construction as well as significant winter storms. Notable is the reduction in sediment delivery from the prominent source categories, with the exception of streamside landslides, since the all-time high in 1988-1997.

Loading Capacity and Allocations

The sediment loading capacity of the Upper Elk River waterbody is based on natural sediment loading with an allowance for management-related increases. Chapter 5 of the Staff Report explores a number of ways for establishing the appropriate proportion above natural background sediment loading which results in protection of existing beneficial uses (e.g., domestic and agricultural water supply, recreation, cold freshwater habitat), prevention of nuisance flooding, and attainment of water quality objectives (e.g., suspended material, settleable material, suspended sediment load, and turbidity). The turbidity water quality objective appears to be the objective most sensitive to management activities. The turbidity objective allows no more than 20% above naturally occurring background levels. Based upon correlation of turbidity, suspended sediment loads, and total sediment loads, the loading capacity is set at 120% of natural sediment loading. The Source Analysis finds that natural sediment loading is 68 $yd^3/mi^2/yr$, so the TMDL is set at 120% of 68 $yd^3/mi^2/yr$, or 82 $yd^3/mi^2/yr$.

A margin of safety ensures that the total maximum allowable load never results in exceedence of ambient water quality objectives, considering seasonal variation and other factors. The sediment source analysis incorporates numerous inherent margins of safety by frequently identifying the conservative approaches to sediment loading estimation. Further, the use of the turbidity water quality objective as the basis for establishing the TMDL ensures attainment of the most sensitive of the objectives. As such, no explicit margin of safety is included in the TMDL equation. The TMDL equation is:

$$\textbf{TMDL} = 82\ (yd^3/mi^2/yr) = 68\ (NB) + 0\ (WLA) + 14\ (LA)$$

The sediment loading associated with instream deposits within in the low gradient reaches of Upper Elk River consumes the load allocation. Staff propose that the entire volume of instream stored sediment must be remediated over a 10 year period to achieve the TMDL.

The management load allocation of 14 $yd^3/mi^2/yr$ is divided among the hillslope sediment source categories proportional to their estimated rates. An estimated 97-98% reduction in contemporary management-related sediment loading is necessary to attain the TMDL load allocations. Staff propose their attainment of the hillslope load reductions by 2033.

Numeric Targets

Numeric targets (targets) are a required component of TMDLs and provide an interpretation of narrative water quality objectives. Past regulatory and implementation actions in the watershed were insufficient to prevent nuisance and protect water quality and beneficial uses from the adverse effects of management-related sediment loads to Elk River.

Natural and management-related hydrologic factors associated with sediment loads in Upper Elk River have led to non-attainment of water quality objectives for sediment. An important component in preventing and recovering impaired water quality is to consider impacts to hydrology at the watershed scale. Staff finds that a water quality objective for watershed hydrology, based on watershed health and aquatic ecological functioning, would provide clarity in the connection between watershed hydrology, sediment loading, beneficial use protection, and prevention of nuisance. Staff propose that a watershed hydrology objective, already developed jointly by the North Coast and San Francisco Regional Water Board's be considered in a future action by the Regional Water Board, either specifically for Elk River, as part of Regional water quality protection planning.

Hillslope numeric targets for the hillslope management-related sediment source categories are proposed that collectively describe hillslope conditions that will conform to Basin Plan water quality objectives and TMDL load allocations. Additionally, staff proposes targets for riparian areas and prevention of cumulative watershed effects. Instream numeric targets are proposed for indicators important to cold water habitat and migration. Conditions supportive of salmonids are anticipated to be supportive of water supplies. A proposed in instream numeric target for prevention of nuisance flooding is based upon historic measurements of channel conveyance capacity measurements by USGS.

Implementation Framework

The Upper Elk TMDL implementation framework identifies responsible parties and includes a general description of the tasks needed to control sediment delivery to the

Upper Elk River subbasin. The responsible parties identified; including: Regional Water Board, HRC, GDRC, BLM, and residents/ and other water users.

Factors considered in identifying implementation actions necessary to resolve sediment impairment in Upper Elk River watershed include:

- Implementation of sediment control measures by the primary landowners in the Upper Elk River watershed has been ongoing since 1997.
- Instream deposits of fine sediment in the low gradient stream reaches currently consume the assimilative capacity of Upper Elk River.
- Ongoing sediment deposition continues to impede recovery of beneficial uses of water. Significant hillslope and instream load reductions are necessary to restore the assimilative capacity of the stream system.
- Total sediment delivery to the fluvial system associated with land use activities needs to be reduced by 97-98% from contemporary values (2001-2011) in order to meet the sediment load allocation of 120% above natural sediment loads.
- In addition to actions needed to resolve sediment-related threats to fisheries and water supplies, progress is also needed toward recovery of channel and floodplain conditions resulted from the storage of instream deposits from past and ongoing sediment discharges.
- Direct recovery actions in the low gradient stream reaches of the Upper Elk River watershed, combined with sediment load reductions from management-related hillslope sediment sources, are necessary to restore ecosystem functions, abate nuisance flood conditions, attain ambient water quality objectives and recover beneficial uses. The primary objective of any direct recovery action in the lower portion of the Upper Elk River would be to contain bankfull flows (1.5-2 year recurrence interval), while minimizing any adverse effects to upstream and downstream reaches, infrastructure, and land uses.
- The implementation framework is constructed to optimize coordination of assessment and treatment of instream deposits in the lower portion of the Upper Elk River among the primary landowners (HRC, BLM, and GDRC), affected private residents, non-profits and assistance organizations, and those with technical expertise in fisheries restoration, hydrodynamics, sediment transport, fluvial geomorphology, and related fields. Such partnerships can ensure in-kind services and cost-shares to achieve favorable positions for receipt of grant funding from state and federal agencies to support implementation actions.
- The implementation program framework reflects the consideration and balancing of various relevant factors including, cost, equity, magnitude of impact, degree of management controls in place, feasibility, and probability of success.
- Water supplies are best tailored for community-based solution

CHAPTER 1. Introduction to the Technical Sediment Total Maximum Daily Load for the Upper Elk River

Key Points

- Water quality in the Elk River watershed is impaired from excessive sediment loads from land use activities conducted in the forested portion of the watershed.
- The Elk River watershed was delineated into three subbasins based on watershed scale similarities. The three subbasins are the Upper Elk River, the Little South Fork Elk River and the Lower Elk River. The focus of this technical sediment TMDL is on the Upper Elk River subbasin.
- The Upper Elk TMDL was developed using the framework established under the federal Clean Water Act, the state's Porter Cologne Water Quality Control Act and the Basin Plan. The Upper Elk TMDL was developed to support all existing beneficial uses of water present in the Elk River watershed, including the wetland specific water quality objectives adopted into the Basin Plan 2003.

This document, *Staff Report to Support the Technical Sediment Total Maximum Daily Load for the Upper Elk River* (Staff Report) presents the North Coast Regional Water Quality Control Board (Regional Water Board or Board) staff's assessment of data and information relevant to the issue of sedimentation in the Upper Elk River. Staff's assessment includes 1) an overview of the watershed, 2) the development of a problem statement, 3) an analysis of sediment sources, 4) an analysis of the watershed's sediment overall loading capacity and individual load allocations, 5) numeric targets describing the watershed conditions necessary to attain the load allocations, and 6) a framework for the implementation program needed to ensure that appropriate actions are taken to restore the water quality in the Upper Elk River. The Elk River is located in northwestern California (Figure 1.1).

The primary purpose of the Upper Elk TMDL is to estimate the loading capacity of the Elk River system with respect to the total sediment loads delivered from the Upper Elk River that can be transported to the mainstem Elk River and its tributaries without causing an exceedence of water quality standards (including beneficial uses of water and water quality objectives) or causing/contributing to nuisance flooding conditions. The Upper Elk TMDL will form the basis for the future action or actions of the Regional Water Board to establish appropriate sediment discharge controls.

In 1998, the Regional Water Board determined that excessive sediment loads in Elk River and its tributaries resulted in the impairment of beneficial uses of water and the non-attainment of water quality objectives. Beneficial uses of water and water quality objectives are collectively referred to as water quality standards. The primary adverse impacts of elevated sediment loads in the Elk River and its tributaries are associated with impacts to domestic and agricultural water supplies and cold water fish habitat. Numerous sensitive species of fish, including state and federally-listed species of concern reside in the

Elk River and its tributary streams. Elevated sediment loads also result in nuisance conditions and may adversely affect contact and non-contact recreational uses.

Regional Water Board staff involved the public during the development of the Upper Elk TMDL in several ways, including development and maintenance of a website dedicated to the Elk River TMDL development process, developing an interested parties mailing list, engaging in formal and informal presentations and information gathering with stakeholders, and making presentations to the Regional Water Board throughout the TMDL development process. These public participation opportunities have ensured that staff is aware of public concerns regarding watershed conditions and the regulatory actions needed to recover sediment impaired conditions in Upper Elk River.

The Staff Report includes:

1. An introduction to the TMDL which presents the geographic scope, or delineation, of the Upper Elk TMDL and a summary of the regulatory framework, including water quality standards, used to develop the TMDL (Chapter 1);
2. A watershed overview of the natural and land use conditions present in the Upper Elk River (Chapter 2);
3. A "problem statement" that describes the physical mechanisms that cause sediment impairment and nuisance flooding in Upper Elk River (Chapter 3);
4. A "source analysis" that describes the major sources of sediment loads from both natural and management-related sediment discharge sites into Upper Elk River and its tributaries. (Chapter 4);
5. A linkage analysis and estimate of the "loading capacity" of the riverine system that identifies the total sediment loads that can be delivered to Upper Elk River and its tributaries without causing exceedence of water quality standards or the creation of nuisance flooding conditions. The TMDL sets forth "load allocations" by which the natural and management-related loads are distributed so as not to exceed the loading capacity, including a margin of safety and a schedule for attainment of the TMDL (Chapter 5);
6. Numeric targets for instream and hillslope indicators that describe conditions in which narrative water quality objectives are met, beneficial uses are protected and restored, and flooding nuisance is abated and prevented (Chapter 6); and
7. The framework describing the implementation strategy including regulatory and non-regulatory actions to attain the load allocations. (Chapter 7).

1.1 Delineation of the Upper Elk River Watershed

The Elk River watershed, from the headwaters streams to its confluence with Humboldt Bay, includes 20 different subbasins with varying characteristics and land uses (Figure 1.2). For the purpose of this analysis, staff has subdivided, or delineated, the Elk River watershed into three distinct waterbodies (Figure 1.3). The delineation of the Elk River into these distinct subbasins, or waterbodies, was based upon:

- Predominance of land use;
- Location of sediment sources; and
- Extent of beneficial use impairment and nuisance flooding conditions.

Consideration of these factors resulted in the Elk River watershed being delineated into:

- Upper Little South Fork Elk River;
- Upper Elk River, and
- Lower Elk River.

More information on the delineation of the Elk River watershed into three waterbodies is presented in Appendix 1-A.

This is the sediment TMDL for the Upper Elk TMDL. An analysis of the Upper Little South Fork Elk River and the Lower Elk River subbasins will be conducted at a future date, as necessary.

The Upper Elk River was delineated to include all areas within the upper 17 subbasins (Figure 3, areas 4 to 17) where industrial timber harvesting is the dominant land use. The downstream boundary of Upper Elk River waterbody was defined to include portions of the Lower Elk River subbasin (Figure 2, area 3):

- Parcels that are zoned for industrial timber harvest production
- Parcels which rely on Elk River for domestic water supplies; and
- Parcels, other than those zoned exclusively for agriculture that are within the 100-year floodplain as indicated on the 1987 floodplain map produced by the Federal Emergency Management Agency (FEMA).

The downstream boundary of the Upper Elk River waterbody was established because the area upstream of that location includes the industrial timberlands from which the discharge of sediment has been documented and cleanup activities are underway. It incorporates the most impacted reaches of Elk River, including those areas where properties are dependent on the river for domestic supply and neighborhoods are flooded.

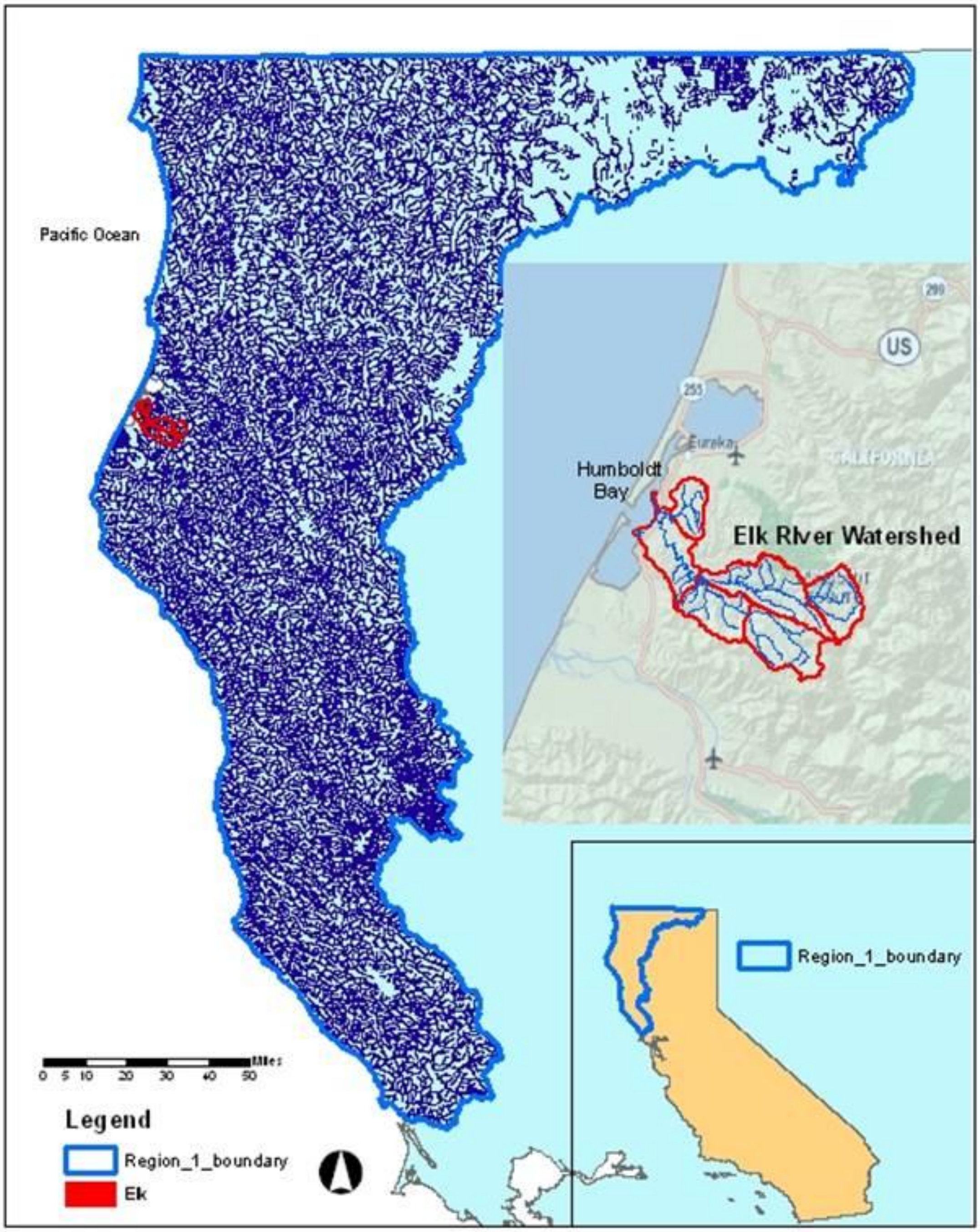
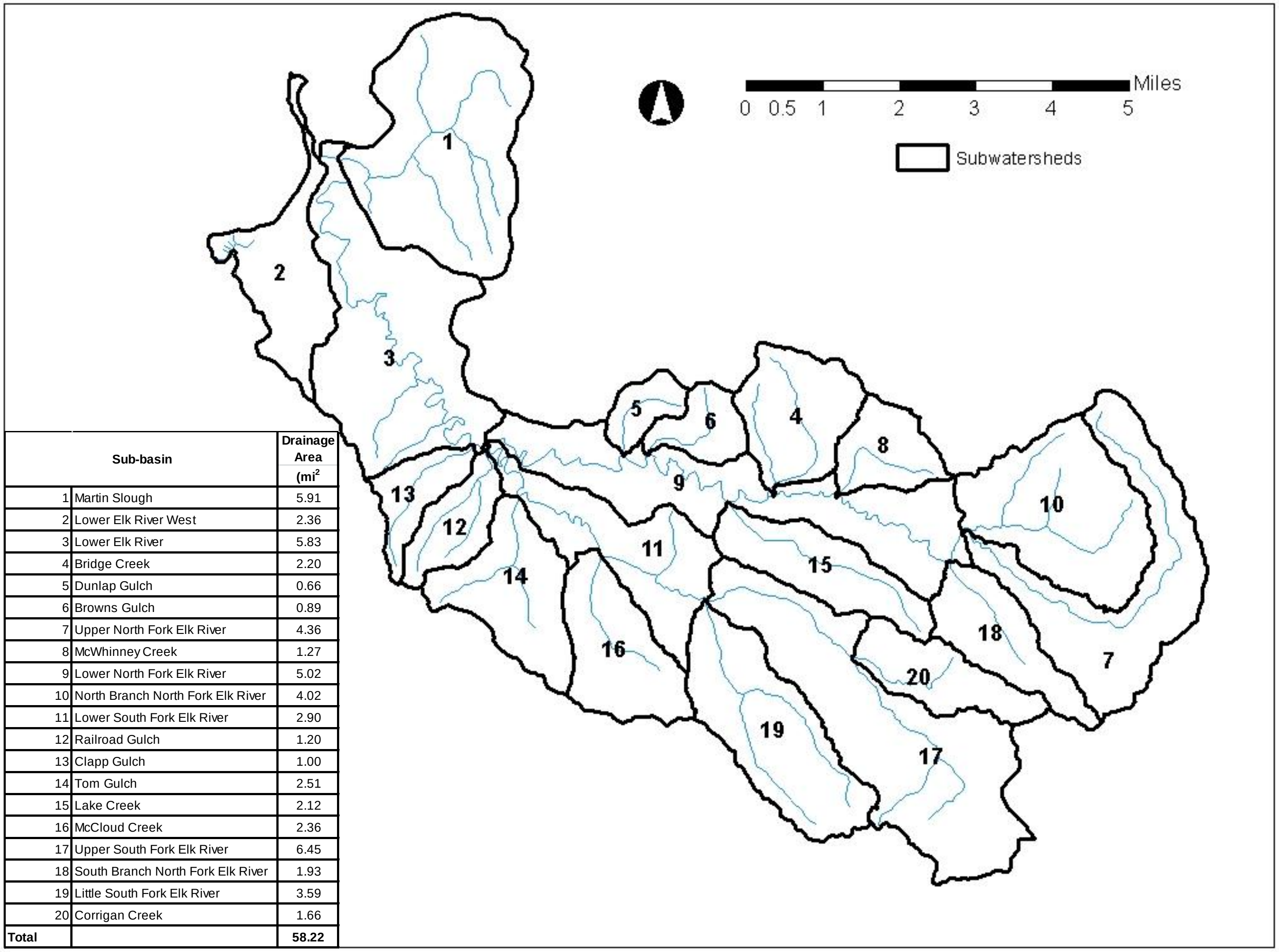


Figure 1.1 Locations of the North Coast Region (Region 1) and the Elk River watershed within California (Regional Water Board, 2009).



	Sub-basin	Drainage Area (mi2
1	Martin Slough	5.91
2	Lower Elk River West	2.36
3	Lower Elk River	5.83
4	Bridge Creek	2.20
5	Dunlap Gulch	0.66
6	Browns Gulch	0.89
7	Upper North Fork Elk River	4.36
8	McWhinney Creek	1.27
9	Lower North Fork Elk River	5.02
10	North Branch North Fork Elk River	4.02
11	Lower South Fork Elk River	2.90
12	Railroad Gulch	1.20
13	Clapp Gulch	1.00
14	Tom Gulch	2.51
15	Lake Creek	2.12
16	McCloud Creek	2.36
17	Upper South Fork Elk River	6.45
18	South Branch North Fork Elk River	1.93
19	Little South Fork Elk River	3.59
20	Corrigan Creek	1.66
Total		**58.22**

Figure 1.2 Subbasins in the Elk River watershed (Stillwater, 2007).

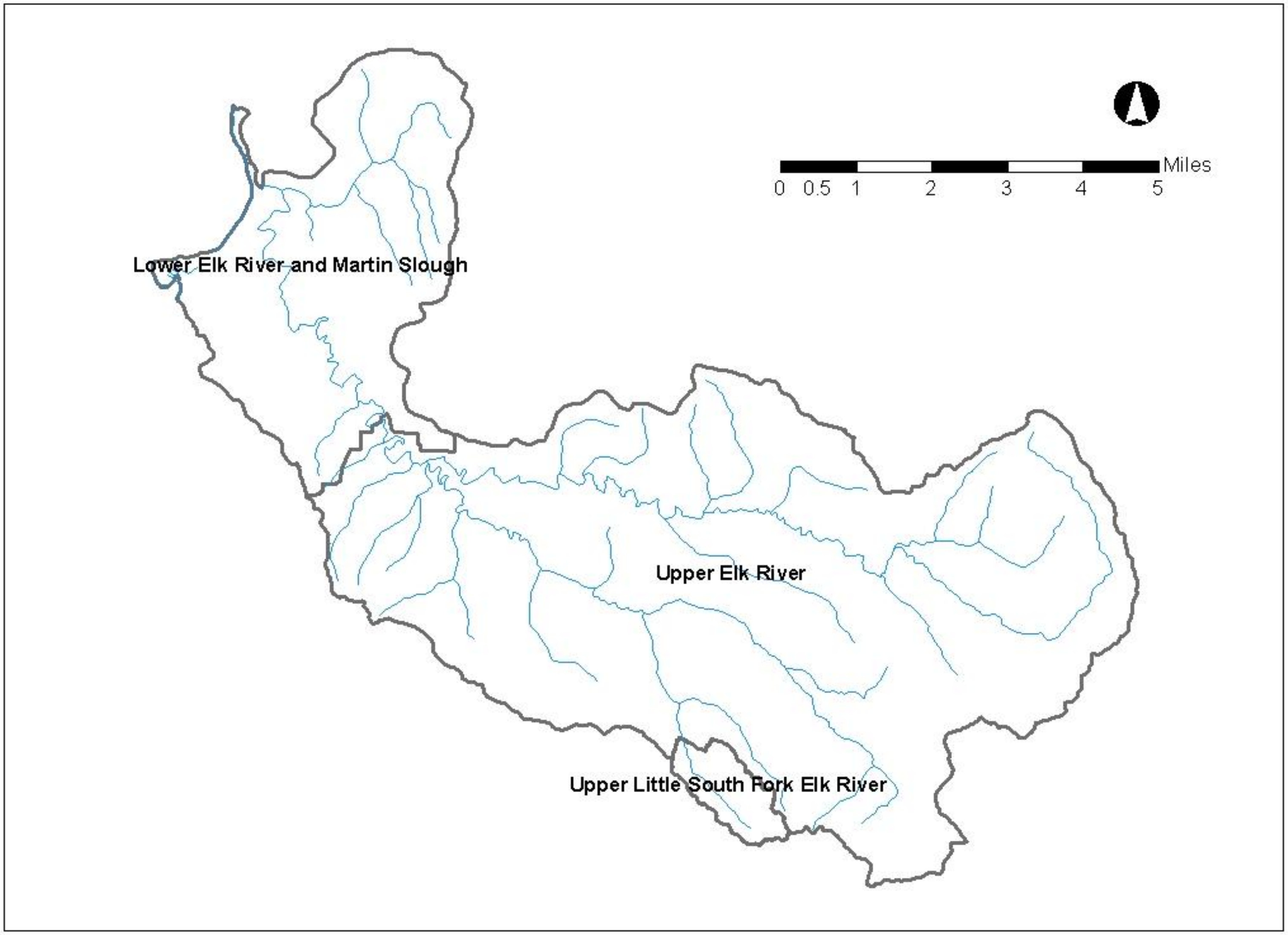


Figure 1.3 Delineation of Elk River watershed into 3 waterbodies (Regional Water Board, 2012).

1.2 Regulatory Framework/Water Quality Standards and TMDL Development

The regulatory framework used in the development of the Upper Elk TMDL includes consideration of federal, state and local regulatory requirements. Water quality standards, including beneficial uses of water and water quality objectives, are the benchmarks used in the development of the Upper Elk TMDL. Water quality standards for waters of the North Coast Region are contained in the *Water Quality Control Plan for the North Coast Region* (May, 2011), commonly referred to as the Basin Plan.

The North Coast Regional Water Board is one of nine regional water boards that function as part of the California State Water Board system within the California Environmental Protection Agency. The Regional Water Board is the California State agency responsible for the protection of water quality in the Elk River watershed. The Regional Water Board implements the Porter-Cologne Water Quality Control Act (Porter Cologne)[1] which is the state law governing the water quality protection activities as authorized by the State Legislature. The Regional Water Board, in part, is also tasked with overseeing the requirements of the federal Clean Water Act (CWA).

The State Water Resources Control Board (State Water Board), with Regional Water Board's input, periodically identifies waters that are not meeting water quality standards. The State Water Board is required, under Section 303(d) of the federal CWA, to develop a list of those waterbodies in California where technology-based effluent limits or other legally required pollution control mechanisms are not sufficient or stringent enough to meet the water quality standards applicable to such waters. This list, referred to as the *Section 303(d) List of Impaired Waterbodies* (303(d) List) also identifies the pollutant/stressor causing the impairment, and establishes a prioritized schedule for developing a control plan to address the impairment. The United States Environmental Protection Agency (USEPA) has federal oversight authority and may approve or disapprove TMDLs developed by the State. If the USEPA disapproves a TMDL then USEPA is required to establish a TMDL for the listed waterbody.

Placement of a waterbody on this list generally triggers development of a pollution control plan, referred to as a TMDL. In California, the authority and responsibility to develop TMDLs rests with the Regional Water Boards. The TMDL process leads to a "pollution budget" which quantifies the pollution reductions necessary to restore the health of a polluted body of water. The TMDL process includes a technical analysis which provides a quantitative assessment of water quality problems, contributing sources of pollution, and the required pollutant load reductions. The TMDL process also includes a course of action to implement the control actions necessary to restore and protect the beneficial uses of an individual waterbody impaired from loading of a particular pollutant. This Upper Elk TMDL includes the technical analysis. It does not include a proposed course of action, at this time. But, it does include an implementation framework designed to inform future action.

[1] Water Code §§ 1300 et seq.

There are a number of specific components, as described in Section 1.3 below, which must be included in a TMDL in order for USEPA to approve it.[2] Most essentially, a TMDL is the calculation of the maximum amount of a pollutant that a waterbody can receive and still protect the beneficial uses of water. This calculation also includes a margin of safety and consideration of seasonal variations and other critical conditions. In addition, the TMDL calculation expresses the load reductions needed to meet water quality standards by allocating allowable loads to individual pollutant sources in the watershed.

Two basic approaches to TMDL development are available to the Regional Water Board. These approaches include:

- Development of a "technical" TMDL, which includes the background information and technical analysis needed to support calculations of the loading capacity and load allocations for an impaired waterbody. A technical TMDL does not include implementation or monitoring plans.
- Development of a "complete" TMDL includes the technical components as well as an implementation and monitoring plan. There are numerous options for implementing the load allocations developed in a TMDL, including the adoption of a TMDL action plan into the Basin Plan or the adoption of a WDR.

Consistent with recommendations by the Regional Water Board, Elk River was added to the 303(d) List in 1998. The listing was based on evidence of the discharge of excessive sedimentation/siltation loads from land management activities in the upper portion of the watershed. Water quality problems cited under the listing include:
- Sedimentation and threat of sedimentation;
- Impaired domestic and agricultural water quality;
- Impaired spawning habitat;
- Increased rate and depth of flooding due to sediment; and
- Property damage.

The Elk River, from its confluence with Humboldt Bay to its tributary headwater streams continue to be identified as an impaired waterbody on subsequent 303(d) lists, including the latest list approved by USEPA in 2010.[3]

Water Quality Standards

Under federal law a water quality standard consists of four basic elements:
1. Designated uses of a waterbody;
2. Water quality criteria to protect designated uses;
3. An antidegradation policy to maintain and protect existing uses and high quality waters; and
4. General policies addressing implementation issues.

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[2] 40 CFR § 130.2 and 130.7) and CWA section 303(d).

[3] <http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml> (as of February 15, 2013).

Porter Cologne modifies the federal language to refer to designated uses as “beneficial uses” and water quality criteria as “water quality objectives”, which includes the State Water Board’s antidegradation policy (Resolution 68-16). Porter Cologne[4] also requires a “program of implementation” for water quality protection in California. A program of implementation includes actions necessary to achieve objectives, a time schedule for the actions to be taken and monitoring to determine compliance with water quality objectives and protection of beneficial uses of water.

The Basin Plan establishes the regions’ water quality standards, including the standards that apply to the Elk River and its tributaries. The Basin Plan includes, in part, the definition and identification of beneficial uses of water (Chapter 2), a compilation of the water quality objectives in effect in the region (Chapter 3) and a section relative to the region’s implementation program (Chapter 4).

In accordance with the federal CWA, TMDLs are set at a level necessary to achieve applicable water quality standards.

Beneficial Uses of Water

Beneficial uses of water (beneficial uses or uses) are those uses of water that may be protected against quality degradation such as, but not limited to, domestic, municipal, agricultural supply, industrial supply, power generation, recreation, aesthetic enjoyment, navigation, preservation and enhancement of fish, wildlife and other aquatic resources or preserves.[5]

Beneficial uses for the Elk River are identified, in large part, in Table 2-1 of the Basin Plan under the Eureka Plain (Hydrologic Unit 110.00) subheading. The beneficial uses of water identified in the Basin Plan for the Elk watershed are presented below in Table 1-1.

[4] CWC § 13242.
[5] CWC § 13050 (f).

Table 1.1 Beneficial uses of water in the Elk River watershed (as Identified in Basin Plan Table 2-1 (2011).

Municipal Water Supply (MUN)	Non-Contact Water Recreation (REC-2)
Agricultural Supply (AGR)	Commercial or Sport Fishing (COMM)
Industrial Service Supply (IND)	Cold Freshwater Habitat (COLD)
Industrial Process Supply (PRO)	Wildlife Habitat (WILD)
Groundwater Recharge (GWR)	Rare, Threatened, or Endangered Species (RARE)
Freshwater Replenishment (FRSH)	Migration of Aquatic Organisms (MIGR)
Navigation (NAV)	Spawning, Reproduction, and/or Early Development (SPWN)
Hydropower Generation (POW)	Aquaculture (AQUA)
Water Contact Recreation (REC-1)	Estuarine Habitat (EST) (applies only to estuarine portion of the watershed)

Of the 18 identified beneficial uses, at least 5 are considered impaired; including municipal/domestic water supplies; agricultural water supply, cold freshwater habitat, and to a lesser extent both recreational uses.

In 2003, the Regional Water Board adopted three additional beneficial uses of water for application in the North Coast Region. These additional uses include flood peak attenuation/flood water storage (FLD), wetland habitat (WET) and water quality enhancement (WQE). These beneficial uses were adopted by the Regional Water Board as part of the region's ongoing planning process and are included in the beneficial use chapter of the Basin Plan (Chapter 2). Headings for these beneficial uses are included in Table 2-1 of the Basin Plan. However, at the time of their adoption in 2003 there were no staff resources available to update Table 2-1 so as to identify them as existing or potential uses in individual waterbodies. As such Table 2-1 does not currently provide a complete reflection of the existing beneficial uses of water in the Elk River watershed. Federal antidegradation regulation[6] requires that all beneficial uses of water be protected regardless of whether or not the use is formally designated in the Basin Plan. As described below, it is staff's assessment that FLD, WET, and WQE are existing beneficial uses in the Elk River watershed, As such the Upper Elk TMDL, including implementation framework, is developed to ensure protection and restoration of these existing beneficial uses as well as those identified in Basin Plan Table 2-1.

The information necessary for the Regional Water Board to consider updating Basin Plan Table 2-1 to include these additional existing uses of water for the Elk River is presented in Appendix 1-B. Regional Water Board staff recommend that Basin Plan Table 2-1 be revised either as part of the Board's consideration of any Basin Plan amendment relative to the Elk River or as part of the Basin Plan amendment to revise Table 2-1 as directed under the 2011 Triennial Review. See the Regional Water Board's basin planning web page[7] for more information relative to the Triennial Review and ongoing basin planning activities in general.

6 40 C.F.R. § 131.12.
7 http://www.waterboards.ca.gov/northcoast/water_issues/programs/basin_plan/triennial_review.shtml (as of February 15, 2013).

Water Quality Objectives

The Regional Water Board is responsible for establishing water quality objectives which, in the Board's judgment, are necessary for the reasonable protection of beneficial uses and for the prevention of nuisance conditions.[8] Water quality objectives form the basis for establishment of waste discharge requirements, waste discharge prohibitions, maximum acceptable cleanup standards and for other Regional Water Board actions, such as establishment of TMDLs.

The natural ambient condition of each waterbody is uniquely defined by a number of watershed characteristics, including but not limited to: geology, slope, climate, land cover, etc. Water quality objectives (objectives) are contained in Chapter 3 of the Basin Plan and define, in narrative or numeric form, the minimum ambient water quality conditions necessary to support beneficial uses. For example, the ambient water quality necessary to protect swimmers is based on human health studies and the potential for contaminants to be accidentally ingested. Similarly, the ambient water quality necessary to protect salmonids is based on aquatic life studies and the requirements of developing eggs and alevin for cold, clean, well-oxygenated water through the intergravel environment.

The Basin Plan contains four sediment-related water quality objectives. All of these objectives are applicable to the Upper Elk River. The sediment-related objectives are presented below in Table 1.2.

Table 1.2 Sediment related water quality objectives (as identified in the Basin Plan)

Suspended Material	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Settleable Material	Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses.
Suspended Sediment Load	The suspended sediment load and suspended sediment discharge rate of surface water shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
Turbidity	Turbidity shall not be increased more than 20 percent above naturally occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.

8 CWC § 13241.

Porter Cologne and the Basin Plan also contain a provision for "controllable water quality factors". The controllable factors provision is presented below:

> Controllable water quality factors shall conform to the water quality objectives contained herein. When other factors result in the degradation of water quality beyond the levels or limits established herein as water quality objectives, then controllable factors shall not cause further degradation of water quality. Controllable water quality factors are those actions, conditions, or circumstances resulting from man's activities that may influence the quality of the waters of the State and that may be reasonably controlled.

If controllable water quality factors are affecting the support of water quality standards then actions must be taken to bring those factors into conformance with Basin Plan objectives such that beneficial uses of water are maintained and restored.

In addition, Porter Cologne[9] defines nuisance to mean anything which meets all of the following requirements:

> (1) Is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property.
>
> (2) Affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted upon individuals may be unequal.
>
> (3) Occurs during, or as a result of, the treatment or disposal of waste.

Any activity with the reasonable potential to result in the discharge of waste to a water of the State may be issued a Waste Discharge Requirement (WDR) by the Regional Water Board. A WDR establishes the provisions and limitations necessary to ensure that the waste discharge will not result in a lowering of ambient water quality, and in no case a lowering below the levels described by the objectives. A WDR is designed to control the amount, quality, and manner in which wastes enter a water of the State. Appropriate discharge limits are established by assessing the assimilative capacity of the waterbody for the constituents of concern and distributing some portion of that capacity to the waste discharge in question, considering the other discharges in the basin, the best practicable treatment technologies and pollutant control measures, and that which will bring maximum benefit to the people of the State. The Regional Water Board is in no way obligated to distribute the entire assimilative capacity of the waterbody.

For surface waterbodies whose ambient water quality exceeds objectives, the total maximum daily load of the constituent of concern must be calculated and the allowable load of the pollutant(s) redistributed to point and nonpoint source discharges, making allowances for natural conditions and a margin of safety. In such a case, existing WDRs must often be revised and new WDRs developed for discharges which were previously unpermitted.

[9] CWC § 13050.

Antidegradation Policies

There are two antidegradation policies applicable to waters in the North Coast Region – a state and a federal policy. The State Water Board antidegradation policy is titled the *Statement of Policy with Respect to Maintaining High Quality Waters in California* (commonly referred as Resolution 68-16). Resolution 68-16 applies to all "waters of the State" which are defined as any surface water or groundwater, including saline waters, within the boundaries of the state. The federal antidegradation policy[10] applies to "waters of the United States"[11] which includes, in part, most surface water in the North Coast Region but excludes groundwater. Both policies are incorporated in the Basin Plan. Although there are some differences between the State and federal policies, both require that whenever surface waters are of higher quality than necessary to protect the designated beneficial uses, such existing quality shall be maintained unless otherwise provided by the policies.

Program of Implementation

The Basin Plan Chapter 4 describes the program of implementation under which beneficial uses of water will be protected and restored and water quality objectives are achieved. The implementation program includes prohibitions, schedules of compliance, action plans, policies, and guidelines adopted by the Regional Water Board for that purpose. Chapter 6 of this Staff Report describes the proposed framework for the implementation program proposed to achieve the load allocation in the Upper Elk TMDL.

The CWA does not provide a direct regulatory framework to address nonpoint sources of pollution; as such federal National Pollution Discharge Elimination System (NPDES) permits are not applicable to nonpoint sources of pollution. Provisions contained in Porter Cologne, however, clearly mandate the development of a regulatory structure that provides for the control of nonpoint sources of pollution.

In 2004, the State Water Board adopted the *Policy for the Implementation and Enforcement of the Nonpoint Source Pollution Control Program*[12] (NPS Policy). The NPS Policy establishes the elements required of both dischargers and the Regional Water Board in the control of nonpoint discharge. The NPS Policy reiterates the three regulatory approaches that are available to the Regional Water Board, also enabling the Regional Water Board to use its enforcement tools in regulating nonpoint source dischargers that do not comply with the applicable permit, conditional waiver, or Basin Plan prohibition(s).

Two of the permitting approaches available to the Regional Water Board to control the discharge of waste, include: 1) adoption of WDRs or 2) adoption of waivers of WDRs (waivers). The third approach is for the Regional Water Board to adopt conditional

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[10] 40 CFR 131.12.
[11] 40 CFR 230.3(s).
[12] <http://www.waterboards.ca.gov/water_issues/programs/nps/docs/oalfinalcopy052604.pdf> (as of February 15, 2013).

prohibitions into the Basin Plan. The Regional Water Board currently utilizes all three approaches in the implementation of the nonpoint source pollution control program.

WDRs adopted by the Regional Water Board authorize the discharge of waste to waters of the State under the terms and conditions specified in the permit. WDR conditions may include effluent limitations, receiving water limitations or other requirements designed to protect beneficial uses of water, achieve water quality objectives, and prevent nuisance conditions. WDRs are considered for adoption by the Regional Water Board following a publically noticed hearing and consideration of public comments. [13] WDRs are subject to periodic Board review and remain in effect until terminated or revised by the Regional Water Board. [14]

The requirements for a discharger to apply for WDRs may be waived by the Regional Water Board for a specific discharge or a specific category of discharge if the Regional Water Board determines that the waiver is consistent with all applicable state and Basin Plan requirement and is in the public interest. All waivers are conditional and may include specific management practices that are required, so as to be eligible for the waiver. Waivers may not exceed five years in duration without being renewed through a public Regional Water Board adoption hearing. [15]

The Regional Water Board may also control discharges of waste through the inclusion of waste discharge prohibitions[16] into the Basin Plan as part of the region's ongoing basin planning process. The prohibition may be conditional by including specific requirements or conditions under which application or enforcement of the prohibition may be waived. Regional Water Boards may also choose to include conditional prohibitions in the Basin Plan as the primary regulatory tool for specific types of implementation programs – for example, in cases where a Regional Water Board desires to prohibit discharges unless certain procedural or substantive conditions are met.

The Basin Plan contains an *Action Plan for Logging, Construction, and Associated Activities*. This Action Plan contains region-wide waste discharge prohibitions which pertain to the two specific land use activities. The prohibition states:

> 1. The discharge of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature into any stream or watercourse in the basin in quantities deleterious to fish, wildlife, or other beneficial uses is prohibited.
>
> 2. The placing or disposal of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature at locations where such material could pass into any stream or watercourse in the basin in quantities which could be deleterious to fish, wildlife, or other beneficial uses is prohibited.

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[13] CWC § 13263 (a).
[14] CWC § 13263 (e).
[15] CWC § 13269.
[16] CWC § 13243.

1.3 Required Components of a TMDL

The requirements of a TMDL are described in Title 40 of the Code of Federal Regulations, Section 130.2 (40 CFR 130.2), and Section 303(d) of the CWA, as well as in various guidance documents. A TMDL is defined as the sum of the individual point source waste load allocations (*WLA*), nonpoint sources load allocations *(LA)*, load allocation to account for natural background pollutant loads (*NB*) as well the need to provide a margin of safety (*MOS*) to account for uncertainties in the analysis . A TMDL can be expressed by the Equation 1.1:

$$TMDL = NB + WLA + LA + MOS \quad \textbf{(Equation 1.1)}$$

A TMDL includes individual load allocations for all significant sources in the watershed.

A complete TMDL contains all of the following elements:

- *Problem Statement:* Describes which water quality standards are not being attained, which beneficial uses are impaired, and the nature of the impairment.
- *Source Analysis:* Identifies the amount, timing, and point of origin of pollutants of concern, may be based on field measurements and/or models and estimations.
- *Linkage Analysis:* Presents the analysis used to establish the loading capacity based on the data presented in the problem statement and source analysis. Evaluates sediment loading to result in achievement of the relevant standards. This includes consideration of seasonal variations and other critical conditions.
- *Load Allocations:* Allocates responsibility, and identifies the parties to take the specified actions. The allocations may be specific to agencies or persons (businesses), or generally by source category or sector. Allocations of allowable pollutant burdens define TMDL endpoints (e.g., total sediment load from urban runoff). The sum of individual allocations must equal the loading capacity, or the total allowable pollutant burden.
- *Margin of Safety:* Describes how the required margin of safety was incorporated into the TMDL to ensure that the allocations do not exceed the loading capacity. The margin of safety may be implicit (i.e., using conservative assumptions), or explicit (i.e., a discrete allocation assigned to the margin of safety) or a combination of both approaches.
- *Numeric Targets:* Defines the desired future condition of measurable indicators which when collectively achieved will ensure recovery of the beneficial uses of water and result in attainment of water quality objectives and the prevention of nuisance conditions.
- *Implementation Plan:* Describes the plan of action which is expected to result in attainment of load allocation by implementing required source reductions and attainment of the numeric targets. The Implementation Plan identifies enforceable provisions (e.g., WDRs, waivers and/or prohibition) and triggers for Regional Board action (e.g., performance standards).

- *Monitoring/Re-evaluation:* Describes the techniques, locations, and schedule for collecting data sufficient to determine the effectiveness of the Implementation Plan and to test the assumptions made in the assessment.
- *Public Participation* is a crucial component in the development of any successful TMDL to ensure that all relevant issues are considered and incorporated, where applicable, and the relevant control measures can be implemented by the discharger(s).

In addition, the Water Quality Management Planning process[17] requires States to include TMDLs and associated implementation measures and monitoring in the State Water Quality Management Plans.

In contrast to a "complete" TMDL, States can choose to develop what is commonly referred to as a "technical" TMDL. While a technical TMDL presents the necessary background and analysis to support calculations for a complete TMDL neither an implementation nor monitoring plan is included as part of the TMDL. Instead the State has two basic options:

- Forward the support document to USEPA staff so they can complete the development of the components required for USEPA's approval of the TMDL; or
- Pursue alternative approaches to implement the actions necessary to meet a TMDL.

These alternative approaches are presented in the State Water Board *Water Quality Control Policy for Addressing Impaired Waters: Regulatory Structure and Options* (2005).[18] The approaches outlined in this document include:

- Use of a basin plan amendment or other regulation: if the solution to an impairment will require multiple actions of the Regional Water Board that affect multiple person;
- Action is implemented with a single vote of the Regional Water Board: if the solution to an impairment can be implemented by that vote;
- Action is implemented by a regulatory action of another state, regional, local, or federal agency: if the Regional Water Board finds that the solution will actually correct the impairment, the Board may certify that the regulatory action will correct the impairment and if applicable, implement the assumptions of the TMDL, in lieu of adopting a redundant program.
- Action is being implemented by a non-regulatory action of another entity; if the Regional Water Board finds that the solution will actually correct the impairment, the Board may certify that the non-regulatory action will correct the impairment and if applicable, implement the assumptions of the TMDL, in lieu of adopting a redundant program.

17 40 CFR 130.6.

18 < http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/iw_policy.pdf> (as of February 20, 2013).

1.4 Conclusion

A hybrid approach was used in the development of the technical sediment TMDL for the Upper Elk River. While the Staff Report presents calculations of the loading capacity and load allocations necessary to support and restore impaired uses of water and alleviate nuisance flooding conditions in the Upper Elk River (and supporting information), it also includes a framework for the development of a proposed implementation program using a variety of the available approaches.

CHAPTER 2. Overview of the Upper Elk River Watershed

Key Points

- Sediment loads from Upper Elk River are a result of the watershed hydrologic setting, geomorphic and geologic conditions, natural vegetative cover, and type and rate (intensity) of land use activities.
- Since 1997, the Regional Water Board has been taking a variety of regulatory actions to address the discharge of sediment to the Elk River.
- An intensive monitoring regime undertaken by a diverse group of stakeholders was established to provide data relative to hillslope, floodplain, and channel conditions, as well as to provide an extensive collection of water quality data specific to the Elk River

The Upper Elk River watershed is a 44.2 square mile (mi^2) subbasin located in the upper portion of the larger (58.3 mi^2) Elk River watershed located in the coastal temperate rain forest of Humboldt County, California (see Figure 1.1 for location of Elk River and Figure 1.3 for location of Upper Elk River watershed within the larger Elk River watershed). The Elk River watershed originates from relatively steep forested headwater slopes, flows across a grassland coastal plain and enters the central portion of Humboldt Bay. The nonpoint sources of sediment identified during development of the TMDL originated from both natural sources and management-induced sediment sources. No point source sediment discharge was identified in the Upper Elk River waterbody.

Elk River is one of the largest freshwater tributaries of Humboldt Bay. Humboldt Bay is an important economic resource for the local community, including its port and marinas, recreation opportunities, and the numerous shellfish rearing operations. In addition, it provides important habitat for aquatic species. Appendix 2-A describes historic modifications to Humboldt Bay that may influence the sediment loading capacity.

2.1 Hydrologic Setting

The Mediterranean climate of the Elk River basin is characterized by mild, wet winters and a prolonged summer dry season. Mean surface air temperature at the coast fluctuates from 48 °F (9°C) in January to 55 °F (13°C) in June, with summer temperature moderated by fog. Winter rainfall intensity and storm runoff are highly variable due to orographic lifting of moisture-laden, frontal air masses as they encounter the outer Coast Range. Roughly 90% of the annual precipitation occurs as rainfall between October and April. The period of record for rainfall record-keeping began in 1879 in Eureka on Humboldt Bay.[19] Rainfall totals are higher in the Elk River watershed than at the bay, as rainfall increases with elevation (Figure 2.1). Mean annual precipitation ranges from 39 inches at Eureka to 60 inches in Kneeland, located near the top of the watershed (2,657 feet above sea level) and approximately 12 miles inland of the Humboldt Bay.

[19] < http://www.wrh.noaa.gov/eka/ > (as of February 20, 2013).

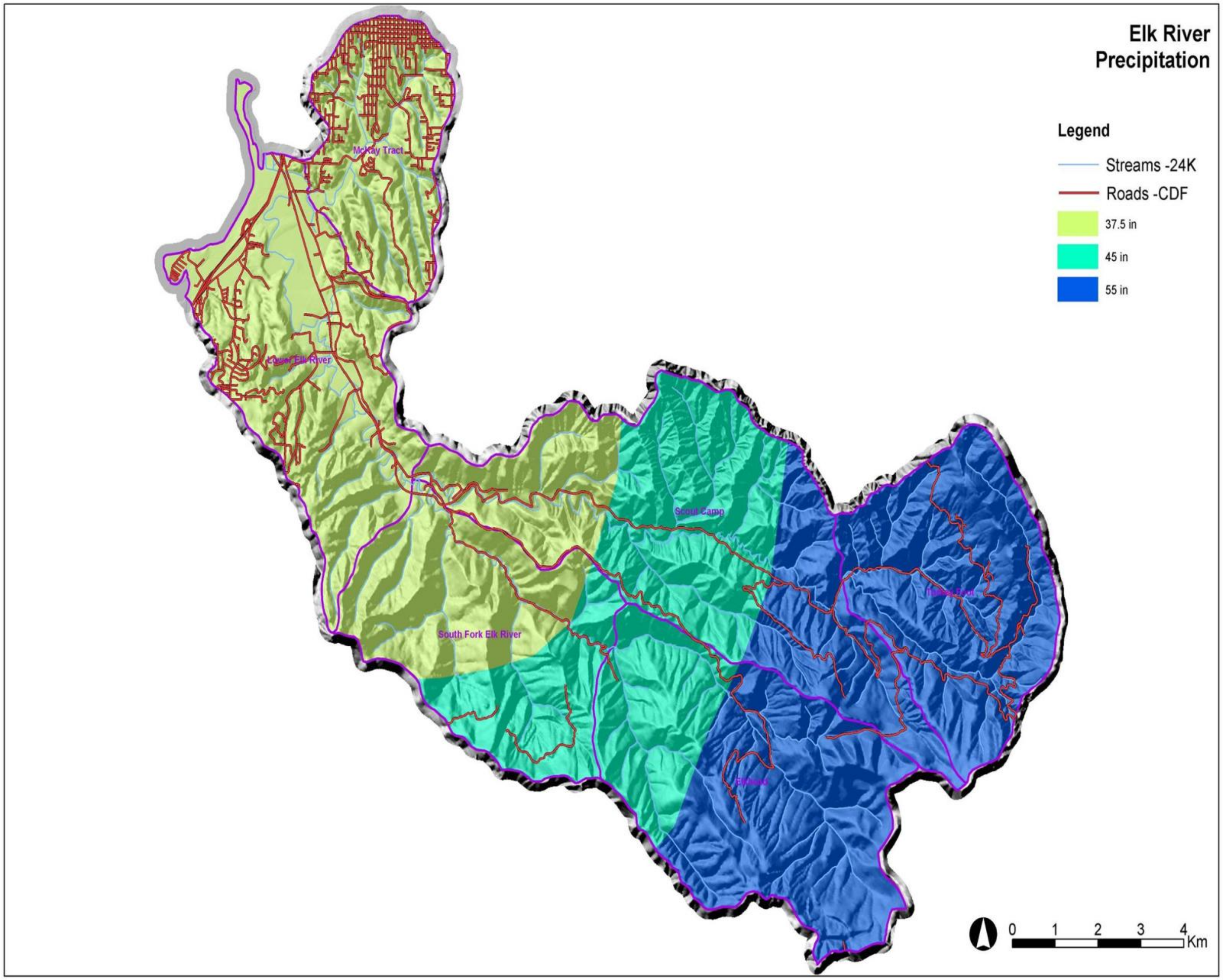

Figure 2.1 Average annual rainfall variation in the Elk River watershed (Stillwater, 2007)

As described in the *Preliminary Assessment of Flooding in Lower Elk River* (Patenaude, 2004), the United States Geologic Survey (USGS), in cooperation with California Department of Water Resources, established a stream gage station[20] on the mainstem of Elk River in 1957. The USGS gage station was located just downstream of the confluence of two of Elk River's main tributaries, North Fork Elk River and South Fork Elk River(which corresponds approximately to the Upper Elk River watershed, see Figure 1.3). The drainage area above this gage station is 43.13 mi^2. Railroad Gulch and Clapp Gulch, respectively, are located upstream and downstream of the historic gage site. The gage was situated where the watershed geomorphology transitioned from steeper forested uplands onto the flatter coastal plain. See Figure 1.2 for general locations of Railroad Gulch and Clapp Gulch subbasins.

Monthly gage records were maintained at this USGS gage station for ten water years from 1958 to 1967.[21] Staff compiled and analyzed available gage records to illustrate hydrologic and hydraulic conditions in Elk River during the 10-year period of record; these data offer a baseline of conditions on the mainstem of the Elk River. Among staff evaluations were estimation of instantaneous annual peak flows using data from the gage station. The estimated recurrence interval of various discharge events are presented in Table 2.1.

Table 2.1 Summary of recurrence interval of various discharge events at USGS gage station on Upper Mainstem Elk River.

Recurrence Interval (years)	Estimated Discharge (cfs)
1.5	2,483
2	2,713
5	3,191
10	3,456
25	3,748
50	3,942
100	4,119
200	4,284
500	4,486

2.2 Geomorphic and Geologic Conditions of the Upper Elk River

In order to provide a more accurate topographic base map layer for use in the Upper Elk TMDL, Regional Water Board staff oversaw a contract that included the development of a fine resolution (1-meter) Digital Elevation Model (DEM) for the entire Elk River watershed. The Upper Elk DEM was generated from LiDAR[22] data. See Appendix 2-B of this Staff Report for more information relative to LiDAR data collection and the development of the DEM for use in the Upper Elk TMDL.

20 USGS Station 11-479700.

21 The term water year refers to the period starting on October 1 of the year previous to the year cited and ends on September 30 of the cited year (e.g. water year 1958 starts October 1, 1957 and ends September 30, 1958).

22 Light Detection and Ranging (LiDAR) is an aerial remote sensing technique in which laser pulses are released towards the earth surface to create a bare earth Digital Elevation Model (DEM).

The DEM[23] was used, in part, to stratify the Elk River watershed into 6 slope categories based on hillslope gradients. The slope categories and percent of Elk River watershed contained within each category are presented in Table 2.2 and mapped in Figure 2.2. The categories were selected based on values that have been established in regulation or have emerged as practical thresholds to aid in the identification and management of landslide hazards (Stillwater, 2007).

Table 2.2 Slope categories based on hillslope gradient and percent of the Upper Elk watershed contained in the slope category

Hillslope gradient	Percent watershed
0-5%	2%
5-15%	10%
15-35%	31%
35-50%	23%
50-65%	17%
>65%	17%

Over half (57%) of the Upper Elk watershed is contained with the slope classes greater than 35%. Sediment delivery rates from sources located on steeper hillslopes are significantly greater than those located on more gentle terrain. Given this relationship, sediment sources on these steeper slopes are considered to be a major factor in establishing accurate sediment delivery rates to the stream network.

The Upper Elk River stream network originates from the northwestern California Coast Range and flows across the low gradient coastal plain to Humboldt Bay. The long-term erosional processes in Elk River are heavily influenced by sea level and its changes due to climate, base level changes and uplift caused by tectonic movement, localized uplift due to folds and faults, and resulting channel incision in response to uplift. Uplift is balanced by erosion via channel incision and steep slopes. Elk River is unique among Humboldt Bay tributaries in that the majority of the watershed is underlain by weak Hookton and Wildcat rocks and sheared Yager rocks, allowing for rapid denudation as the drainage network incises through the formations. Additionally, high uplift rates result in steep slopes and shallow soil.

The Mendocino Triple Junction, located just offshore of Cape Mendocino in northern California, is a geologic junction where the San Andreas Fault meets the Mendocino Fault and the Cascadia Subduction Zone. This is an area where three separate tectonic plates meet the Pacific Plate, the North American Plate and the Gorda Plate. The Gorda Plate is the

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23 The geographic information system (GIS) data developed from the LiDAR collection for Elk River are available at: http://gis.co.humboldt.ca.us/Freeance/Client/PublicAccess1/index.html?appconfig=podgis4 (as of February 13, 2013).

southern-most fragment of the Juan de Fuca plate subducting beneath North America within the Cascadia Subduction Zone. This zone rises and falls during earthquakes. In between earthquakes, uplift results as pressure is exerted at the subduction zone. The uplift occurs both at the ridgeline in Elk River and perhaps at the mouth. Additionally, there is localized uplift related to folding and faulting. The Little Salmon Fault, located near the headwaters of Elk River, also contributes to the seismic activity in the Elk River watershed. There are likely smaller, unmapped faults that also influence localized uplift.

Sea level elevations have changed over time in response to climate changes and other factors. During the interglacial periods of the late Pleistocene, sea level rose and flooded the coastal portion of California numerous times, including the valley and plain of the Elk River, filling it with sediment.

Historical observations indicate that both the North and South Forks of the Elk River were gravel bedded streams, with cobble present in lower South Fork Elk River (RCAA, 2003). Small gravel and sand were observed in the 1960's by USGS in the mainstem Elk River (Patenaude, 2004). Additionally, gravel was apparently mined from the mouth of Elk River to build streets in what is now Eureka (Winzler, 2002). Sediment entering a channel is either transported downstream or is deposited in the stream channel or along its floodplains altering the stream morphology and transport capacity. Sediment transport rates depend on hydrologic conditions, channel characteristics and sediment composition. Larger particles transported along the bed are referred to as bed load. Finer particles are transported within the water column as suspended sediment. Intermediate-sized particles may be suspended for a time and then settle out as flows recede (Reid and Dunne, 2003).

In addition to geomorphic considerations, the nature and predominance of geologic formations underlying a landscape also is a major factor in determining the amount of sediment delivery to stream channels. The rocks that underlie the landscape form the source material for the in-channel substrate, including the presence or absence of spawning gravels. Recent geologic history, uplift, and the intensity of erosion combine to determine how much of this material enters the streams. These geologic materials and processes control slope stability and affect the intensity of land use that can be accommodated without overloading the stream through excess sediment.

Geologic formations (terrains) in the Elk River watershed were mapped by McLaughlin et al. (2000) and Marshall and Mendes (2005) and modified by Stillwater Sciences (2007) as part the TMDL analyses (Figure 2.3). Geologic formations in the Upper Elk River are composed primarily of "young" and erodible rock types. These formations include 1) the Franciscan Complex Central Belt, 2) Yager terrane, 3) Wildcat Group, and 4) Hookton Formation, which due to its relatively young age was grouped with the marine and riverine deposits for consideration in the development of the TMDL.

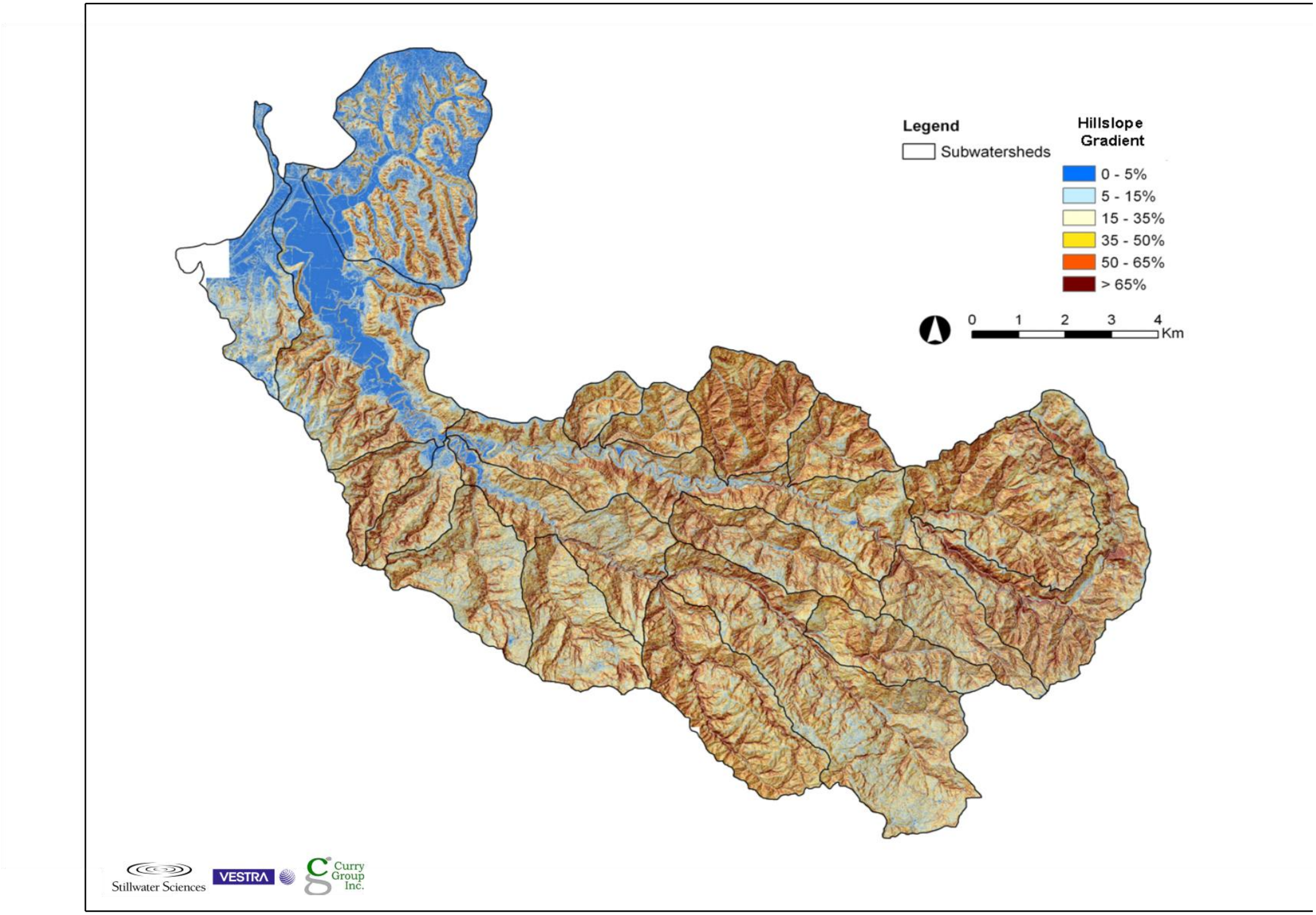

Figure 2.2 Elk River hillslope gradients (as derived from 1-m LiDAR DEM) (Stillwater, 2007).

Figure 2.3 Geologic terrains (formations) in the Elk River watershed[24] (Stillwater, 2007).

24 Subbasin numbers correspond to those identified in Figure 1.2.

The Franciscan Complex Central Belt underlies approximately 6% of the Upper Elk River watershed. Deep-seated landslides and earthflows enclosing blocks of component sandstone are common in the Franciscan Complex Central Belt. These blocks commonly create steep slopes and weather to soils that have little strength and are susceptible to debris slides and debris flows (Marshall and Mendes 2005).

The Yager terrane makes up about 17% of the Upper Elk River watershed, predominantly in the watersheds of the Upper South Fork, Upper North Fork, and North Branch North Fork (Stillwater 2007). The sandstone-dominated rock units commonly form cliffs and exert local base level control where streams have cut down through younger, less resistant deposits upslope. The argillite-dominated rock units are typically deeply weathered and sheared and subject to deep-seated flow failures on moderate slopes (Marshall and Mendes 2005).

The dominant geologic unit in the Upper Elk River watershed is the Wildcat Group which underlies approximately 71% of the Elk River watershed. The Wildcat Group typically consists of poorly to moderately consolidated siltstone and fine-grained silty sandstone that weather to become granular, non-cohesive, non-plastic, clayey silts and clayey sands (Marshall and Mendes 2005). The area underlain by the Wildcat Group is characterized by steep and dissected topography sculpted by debris sliding, and is known for high historical erosion rates from such slope failures. Shallow landslides in the Wildcat Group are commonly associated with headwall swales, inner gorges, and hollows. These are areas where weathered soil and colluvium accumulate over the loosely consolidated parent bedrock. The relatively fine-grained nature of the bedrock produces an overall low permeability rate which increases the risk of slopes becoming saturated with water. The low permeability coupled with the natural orientation of the bedding planes (subparallel to the hillslope) make these areas prone to landsliding (PWA 1998). Subsurface erosion of soil via soil pipes appears to be prevalent in Upper Elk River, at least in the Wildcat Group (PWA, 2000; Buffleben, 2009). Subsurface flow processes influence erosion associated with hillslopes and stream banks directly by seepage and pipe flow processes and indirectly by the relationship of soil properties with soil water pressure. Preferential flow through soil pipes results in internal erosion of the pipe, which may produce gullies by tunnel collapse. The eroded material can clog soil pipes, causing pore water pressure buildup inside the pipes that can result in landslides, debris flows, embankment failures, or of ephemeral gullies (Fox, et al. 2007).

Capping broad, accordant ridge crests in the western part of the Upper Elk River watershed are undifferentiated shallow-water marine and fluvial deposits (gravel, sand, and silt) of the Hookton Formation. These deposits and similar Quaternary marine and river deposits consist of poorly consolidated sand and gravel which are prone to shallow landsliding on the steep hillslopes. Combined, these deposits underlie 4% of the Upper Elk River watershed. Shallow landsliding and deep-seated bedding plane failures are common in Hookton terrane (Marshall and Mendes 2005).

The remaining 1% of Upper Elk River is comprised of Quaternary alluvium, dune sand deposits. These geologically young deposits are poorly consolidated, have relatively high infiltration rates but are extremely erodible if vegetative cover or runoff patterns are altered.

2.3 Vegetation

The maritime coastal climate of the Upper Elk River supports a coniferous lowland forest community dominated by redwood *(Sequoia sempervirens),* western hemlock *(Tsuga heferophylla),* Sitka spruce *(Picea sifchensis),* grand fir *(Abies grandis),* and Douglas-fir *(Pseudotsuga menziesii).* Five vegetation cover types, including conifer/hardwood forest, shrub, herbaceous, agricultural, and urban/bare ground were identified in the Elk River watershed (Figure 2.4).[25]

The presence (or the absence of) and density of vegetative cover is directly related to surface and hillslope erosional processes. Increase in both surface erosion (e.g. sheet wash, gully formation) and hillslope mass wasting events (e.g. debris torrents, rotational landslides) can occur following alteration of the canopy cover, specifically resulting from changes in rainfall interception, and the effects of root distribution and strength on slope stability.

The hillslopes of Upper Elk River are dominated by redwood forests. Natural redwood forest ecosystems are complex as site conditions have evolved over thousands of years. Redwoods can live up to 2,000 years and stand more than 300 feet tall. Redwood is among the world's fastest growing conifers, growing up to one-foot per year. They sprout from either seed or rootstock, taking advantage of an established root system and the energy and nutrient reserves contained within them (SRL, 2009). Both the wood and bark are high in tannins, resulting in resistance to fungal disease and insect infestation. These features contribute to a slow decomposition rate once they fall to the forest floor. The thick bark also protects and insulates the trees from periodic fires.

The redwood forest is source of much organic material, in the form of needle and leaf drop (duff), limbs, and tree fall. All of these sources of organic material contribute to soil formation, protect the soil from erosion and ultimately support networks of microorganisms (fungi, bacteria, microscopic invertebrates, and single celled protozoa). These microorganisms play crucial roles in nutrient cycling, including fixing atmospheric nitrogen into the soil, enhancing the fertility of the forest and contributing to forest health. The organic rich soil supports shrubs and herbaceous understory where other site conditions allow. This understory layer in combination with duff, provides a virtual vegetative blanket over the unmanaged portions of redwood forests.

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[25] The five categories were aggregated from vegetation data compiled as part of the Land Cover Mapping and Monitoring program conducted by the USDA Forest Service Region 5 Remote Sensing Lab and the California Department of Forestry and Fire Protection Fire and Resource Assessment Program.

Redwoods have an intricate network of shallow roots that contribute to the stability of steep forested slopes by maintaining the shear strength of soil mantles. Roots add strength to the soil by anchoring through the soil mass into fractures in the bedrock and laterally to root systems of adjacent trees. Root strength contributes to increasing slope stability across zones of weakness or instability (Ziemer and Swanston (1977); Ziemer (1981), O'Loughlin and Ziemer (1982)). Additionally, roots influence the soil pipe network via providing preferential flow paths and providing stability to protect the capping layer above soil pipes from collapse (Jones, 1994).

The extensive canopy of the redwood forest offers interception, storage and cycling of water through evapotranspiration. Canopy intercepts rainfall, reducing the intensity of rainfall as it reaches the forest floor and decreasing the potential for accelerated soil erosion. Further, the interception allows rainfall to be delivered in a metered fashion over time, tempering the peak flows associated with storms. Reid and Lewis (2007) found that in second growth redwood forests, interception and evapotranspiration accounted for 20% of the overall rainfall, even in the largest of the measured storms.

Un-managed redwood forests can also contribute significant volumes of large diameter trees and branches (large woody debris) that are delivered to or adjacent to watercourses. Large woody debris is an important source of instream wood which is a critical component in the formation of the complex habitat need to support salmonid fisheries. Large woody debris provides cover as well as being an effective mechanism in metering and sorting of instream sediment. When large scale mass wasting events, such as landslides and debris flows, reach a watercourse they deliver not only large volumes of coarse and fine grained sediment; but, they also deliver large woody debris to the stream system (Keller and Swanson 1979; Benda et al. 2002, 2003*a*.)

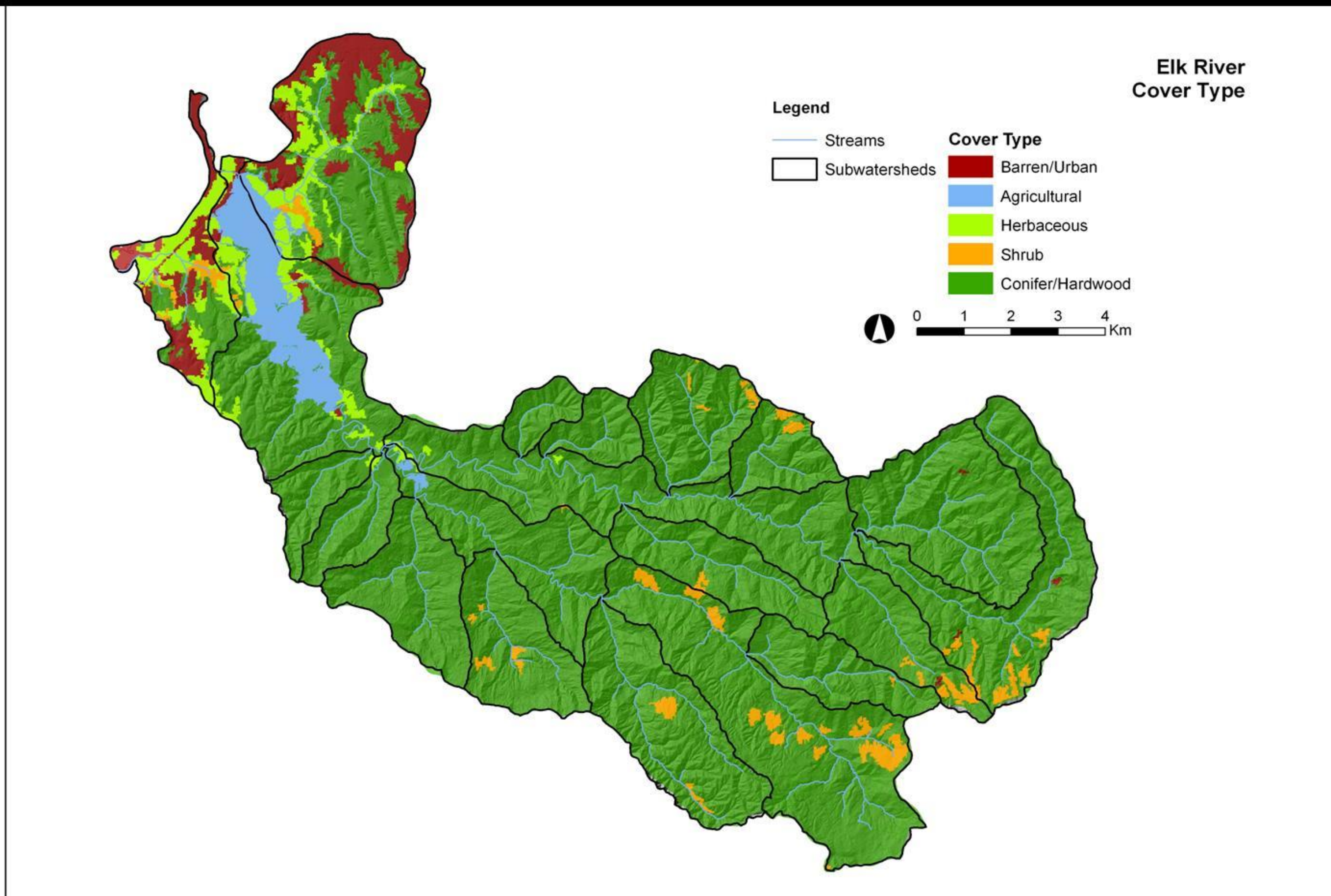

Figure 2.4 Vegetation cover types in the Elk River watershed (Stillwater, 2007).

2.4 Land Use History and Ownership

The current land uses in the Upper Elk River are largely determined by local zoning regulations which have zoned 82% of the area as timber production zone. Most of the Upper Elk River (75%) is privately managed for industrial timber harvest, with the exception of the federally managed Headwaters Forest Reserve (located in the South Fork Elk River subbasin) and a small portion dedicated to private residential and agricultural uses in the lower South Fork Elk River valley. Current ownership in the Upper Elk River is presented in Figure 2.5

The Upper Elk River has been historically recognized as a source for commercial redwood products. The former town of Falk, located on the South Fork Elk River at the mouth of McCloud Creek, was settled in 1884 and served as a mill town and the center of activity for logging in the South Fork Elk River for nearly 50 years. Prior to railroad construction, the predominant means of transporting timber from South Fork to Humboldt Bay was via the river through the use of a splash dam (HBWAC 2005). By the early 1970's, Sierra Pacific Industries, as landowner, had dismantled and removed the mills and other buildings of Falk. At least one small mill and several lumber camps were also located along the North Fork Elk River.

On the North Fork Elk River, the railroad went past the South Branch on the North Fork and up Dunlap and Browns Gulches. On the South Fork Elk River, lines went all the way to the Little South Fork (HBWAC 2005). Timber in the upper South Fork of the Elk River was accessed by railroad above the mill at Falk, requiring nearly a dozen large wooden trestles (Gates 1983; HBWAC 2005). Remnants of the railroad system remain in the watershed in the form of trestles and fills.

By the 1970's, the primary timberland owners in Upper Elk River watershed were:

- Pacific Lumber Company, with approximately 98% of North Fork Elk River, and approximately 14% of the South Fork Elk River (upper South Fork Elk River and upper Little South Fork Elk River).
- Elk River Timber Company, (owned by Sierra Pacific Industries), with approximately 65% of the South Fork (the lower Little South Fork Elk River and the lower South Fork Elk River), and the mainstem tributaries Clapp Gulch and Railroad Gulch.
- Green Diamond Resource Company (formerly Simpson Timber Company) with approximately 15% of the South Fork Elk River watershed (primarily in the McCloud Creek subbasin).

(Figure to be developed)

Figure 2.5 Land ownership in Upper Elk River

Management-related (controllable) factors have combined with natural hydrologic, geologic, geomorphic, and vegetation conditions in Upper Elk River have affected the condition of beneficial uses of water and the water quality necessary to support them. The historic and predominant land use in Upper Elk River is industrial timber harvesting. Timber harvest operations include development of a transportation (road) system to provide access to forested basins, cutting and falling of trees, yarding logs to the transportation system, and movement of logs to a mill. Once the logs are removed, the site may be prepared for replanting by broadcast burning or other site preparation activities. If required the site is then replanted. Each of these activities has potential impacts to water quality, as summarized in Table 4.6. Collectively these impacts affect forest hydrology, alter topography, and can lead to accelerated sediment delivery to the aquatic system.

Timber harvest activities result in canopy removal reducing interception and evapotranspiration rates. This leads to increased effective rainfall reaching the ground with resultant increases in peak runoff and altered hydrographs. Canopy removal results in a decrease in the duff layer and a loss of recruitment trees, critical components in the development of the vegetative layer or “sponge” that used to absorb and buffer raindrop impact. The mycroryzal network is also altered, reducing nutrient cycling. Large wood recruitment to streams is reduced. Compaction from heavy equipment and tree falling operations leads to collapse of existing soil pipes which transported water through a subsurface flow network. The collapse of these pipes leads directly to an increase in the surface drainage (stream) network capable of transporting sediment and more rapid delivery of water downslope. Historic logging left a footprint of unstable fill, inadequate stream crossings, and poorly located roads which continue to contribute sediment to the stream system. In Upper Elk River, these land use activities resulted in violation of the sediment prohibitions. Extensive logging over the past two decades on the geologically weak and tectonically active unstable slopes in the Upper Elk River led to massive and unprecedented landslide sediment discharges. Elk River has been managed for timber products since the late 1800’s. While methods of harvesting, yarding, and transporting logs have changed with new technologies, significant alterations to the forest processes occur with even model timber harvesting activities.

In 1972, the Z’berg-Nejedly Forest Practice Act was passed by the California legislature. This act provided the framework for the first formalized regulation of forest harvest practices in California, including some required level of protection for streams and riparian areas. Compliance with the Forest Practice Act is directed by the Forest Practice Regulations (FPRs) adopted by the California Board of Forestry and Fire Protection with implementation of the FPRs overseen by the California Department of Forestry and Fire Protection (formerly CDF, now Cal Fire[26]). Timber harvest plans (THPs) and Non-Industrial Timber Management Plans (NTMPs) contained the operational and environmental documentation developed by landowners engaged in commercial timber

[26] On January 24, 2007, the informal name for the California Department of Forestry and Fire Protection was changed from CDF to Cal Fire. For the reader’s convenience Cal Fire, rather than CDF, is the primary usage presented in this Staff Report.

harvesting operations. They are submitted to Cal Fire for evaluation, allowing for a comparison of the proposed operation against state and federal regulations, including the FPR and Basin Plan requirements.

Over the long history of timber harvesting in Elk River, logging practices have changed extensively. The footprint of pre-Forest Practice Act logging however, still remains on the landscape in the form of failing watercourse crossings, eroding instream landings and poorly constructed and maintained road systems often built within the sensitive riparian areas of perennial watercourses.

Historically, the Pacific Lumber Company was known for harvesting at 100 to 150 year rotations, not harvesting more than growth, and harvesting via light selection silviculture methods. Staff estimates that Pacific Lumber Company harvested an average of 30% of the canopy and volume during an entry. Elk River Timber Company also operated primarily under selection harvesting; staff estimates they harvested an average of 50% of the canopy and volume per entry.

In 1986, the Pacific Lumber Company, the dominant timber landowner in the Upper Elk River, was taken over by the Maxxam Corporation (Maxxam). Maxxam then split the parent Pacific Lumber Company into three smaller companies, Pacific Lumber Company, Scotia Pacific Corporation, and Salmon Creek Corporation (collectively referred to hereafter as Palco). The new Palco management changed silvicultural practices relying more extensively on even-aged management (e.g. clearcutting) while at the same time accelerating the annual average harvest rate by approximately five-times the previous long-term average. This left the weak, erodible geology and unstable hillslopes extremely vulnerable to storm events such that unprecedented volumes of fine sediment were delivered to the Elk River and its tributaries.

During the period of accelerated harvest, logging was conducted in a manner that did not comply with minimum protections required under the Forest Practice Act; and, it lead to water quality impacts.. For example, from 1995 to 1998, Cal Fire inspectors issued fifty-one Forest Practice Act violations, on 14 separate timber harvesting plans (THPs) located in the North Fork Elk River, (Johnson, 1988). A significant number of these violations were based on the failure of timber operators to install the minimum protection measures required to prevent discharge and threatened discharge of sediment to watercourses. These violations contributed to the Elk River watershed being subjected to significant adverse cumulative impacts to the beneficial uses of water (NCRWQCB, 2000). Over this same time period (1995 to 1998), the Elk River experienced higher than average rainfall. The highly disturbed and erodible landscape, subjected to these significant rainfall events, resulted in numerous large landslides (Figures 2.6 and 2.7) and unprecedented sediment delivery to the Upper Elk River and its tributaries, and significant channel filling in low-gradient reaches. Existing regulatory process that covered individual timber harvest plans and other projects were ineffective at preventing cumulative effects, hence the need to develop a program to recover the beneficial uses of water in Upper Elk River. This TMDL and implementation program will further the recovery program underway in the watershed.

Figure 2.6 Landslide delivering into South Fork Elk River, originating from THP 96-059 (Photo by Elmer Dudik, February 23, 1997).

Figure 2.7 Landslide into West Fork Bridge Creek, originating from THP 1-95-097 and identified in CAO 1-97-115. (Photo by Elmer Dudik, September 9, 1997)

Coincident with this period of accelerated harvesting, the Regional Water Board began receiving complaints from residents living in the Elk River watershed that the water quality and beneficial uses of Elk River were being degraded. Residents who were using surface water for their domestic and agricultural water supplies began noticing that water became very turbid even during minor storms, increased silt in their drinking water and sediment deposition accumulating around their water intakes. Residents reported that associated with the channel filling, the intensity and duration of flooding has increased over historic levels for similar rainfall events.

In response to intense public outcry and in an effort to protect endangered species and some of the last remaining privately owned old-growth redwood groves in the world, the Headwaters Agreement was brokered between the state and federal governments and Maxxam and Palco. Under the Headwaters Agreement, lands owned by Maxxam in the South Fork Elk River watershed (as well as within the adjacent Salmon Creek watershed) were purchased by the state and federal governments. This land was then transferred to public ownership with management to be undertaken by the federal Bureau of Land

Management (BLM) as part of the newly created Headwaters Forest Reserve. Further, the Headwaters Agreement provided for the purchase of all lands owned by Elk River Timber Company and transferred the majority of those lands to Maxxam as partial payment. The remainder of the land (1,845 acres) was transferred to the public to act as a buffer for the Headwaters Forest Reserve.

The Headwaters Agreement also required Palco and the state[27] and federal[28] governments to develop and implement a Habitat Conservation Plan (HCP) and Sustained Yield Plan (SYP). These plans were intended to describe future timber management for endangered species protection and sustainable forestry on the Palco lands, including those in Elk River. The HCP is an incidental take permit for endangered species (i.e. as long as the provisions of the HCP are implemented, the take of an endangered species is incidental to that otherwise legal activity). It does not cover all beneficial uses of water but does address some of the most sensitive aquatic species. The SYP projected decadal timber harvest over the 50-year life of the HCP permit of a maximum of between 140 and 176 million board feet per year across the Palco ownership.

The creation of the Headwaters Forest Reserve and the signing of the Palco HCP/SYP in 1999 did not resolve public concern over timber harvest operations nor did it resolve water quality issues in the Elk River watershed. Over the next two decades there were numerous legal attempts by residents, environmental groups, and resource protection agencies to intervene in timber harvesting activities conducted under Palco management, citing environmental damage and fraudulent business practices.

On January 18, 2007, Palco filed for bankruptcy protection under Chapter 11 of the federal Bankruptcy Code, which permits reorganization under the bankruptcy laws of the United States. On July 8, 2008, the bankruptcy court issued its Judgment and Order confirming a reorganization plan proposed by Marathon Bank Structured Finance Fund L.P. (Marathon) and Mendocino Redwood Company, LLC (MRC). Among other components, this plan consolidated the ownership (and management) of the Scotia sawmill and approximately 210,000 acres of commercial timberlands operations in Humboldt County to the newly formed Humboldt Redwood Company, LLC, (HRC).

On July 30, 2008, MRC/Marathon took legal possession of the timberlands and mill. As a company principle, HRC employs primarily uneven age management (selection and group selection silviculture methods) and has a policy not to harvest old-growth. HRC plans to harvest 55 million board feet per year across the ownership with approximately half (50%) of the current volume from the Upper Elk and the adjacent Freshwater Creek watersheds (combined areas constitute approximately 18% of the ownership) (Pers comm. M. Miles, 2013; Pers Comm. K. Sullivan, 2010).

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[27] Cal Fire and California Department of Fish and Game (now California Department of Fish and Wildlife).

[28] National Oceanic and Atmospheric Administration and US Fish and Wildlife Service.

Green Diamond Resource Company (GDRC) employs primarily even-aged management (clear-cut) silviculture on their 1900 acre ownership. During Palco ownership in the Upper Elk River, GDRC did not conduct much harvesting in the basin. Beginning in 2004, they have operated at an annual harvest of approximately 4% of their ownership.

2.5 Summary of Regional Water Board Regulatory and Non Regulatory Actions in Upper Elk River

Due to documented water quality and beneficial use impairments, the Regional Water Board, its Executive Officer, and staff have taken a variety of regulatory and non-regulatory actions in Elk River to protect and restore beneficial uses of water. During an intensive period of petitions, hearings, investigations, and analyses conducted between 1997 and 2006, the Regional Water Board undertook a series of actions. Among them were the inclusion of Elk River on the 303(d) List, the issuance of Cleanup and Abatement Orders (CAOs) and Monitoring and Reporting Programs (MRPs), undertaking TMDL development, and the development and adoption of watershed-wide Waste Discharge Requirements (WWDRs) for industrial timberland owners in Upper Elk River. Appendix 2-C contains greater detail on Regional Water Board and staff actions that took place between 1997 and 2006.

The data collected and submitted as part of implementation of the CAOs[29] provided a valuable foundation for the sediment inventory necessary to conduct the source assessment, and develop the TMDL. Further, under the CAOs, Regional Water Board and Palco staff developed a site prioritization scheme, treatment schedule, and monitoring program. Implementation of the CAO requirements also served as early TMDL implementation as practices were put in place that began to reduce sediment loads on a programmatic level.

On May 8, 2006, after a long period of development and input from representatives of the public, agencies, and landowners, the Regional Water Board adopted the *Watershed-wide WDRs for Lands Owned by Pacific Lumber Company in Elk River (*Order No. R1-2006-0039). The WWDRs set harvest rate limitations designed to ensure that: a) harvest-related landslides did not create landslide discharges that would, in total, exceed 125% of background landslide rates, and b) that peak flows resulting from canopy removal did not exceed a nuisance threshold defined by floodwaters limiting access and egress at one location on North Fork Elk River where the management induced increase in peak flows

[29] CAO No. R1-2002-0114 for Scotia Pacific Holding Company, The Pacific Lumber Company, North Fork Elk River (requires identification, prioritization, and cleanup of controllable sediment source sites identified in 1998 sediment source inventory);
CAO No. R1-2004-0028 for Scotia Pacific Holding Company, The Pacific Lumber Company, South Fork and Mainstem Elk River (requires identification, prioritization, and cleanup of controllable sediment source sites).
CAO No. R1-2006-0055 for Scotia Pacific Holding Company, The Pacific Lumber Company, North Fork Elk River (requires identification, prioritization, and cleanup of controllable sediment source sites; replaced Order No. R1-2002-0114.

could easily be quantified and linked to flooding over a public roadway. An MRP associated with these WWDRs requires continued monitoring of turbidity, suspended sediment, and streamflow throughout the basin, as well as maintenance of a landslide inventory and monitoring of stream channel conditions.

Additionally, on August 8, 2006 the Regional Water Board adopted WWDRs for GDRC's timber harvesting operations in the South Fork Elk River watershed (Order No. R1-2006-0043). This Order incorporated elements of the process used in the Palco CAOs for identification, scheduling, treatment, and monitoring of sediment discharge sites. An MRP was issued in concert, requiring similar monitoring to that required of Palco. The development of consistent approaches to redressing sediment sources, including monitoring protocols, across the Elk River watershed is resulting in a robust data set that will be extremely useful in making management decisions and documenting compliance with the TMDL. The Regional Water Board has since adopted two ownership-wide WDRs for GDRC, including a road WDR[30] and a timber harvesting WDR[31], which together provide programmatic permitting coverage from the Regional Water Board. The South Fork Elk River Management Plan, described in the timber harvesting WDR, contains provisions specific to their Elk River ownership. Upon adoption of the Upper Elk TMDL, it is envisioned that the South Fork Elk River Management Plan will be revised to reflect the findings of the Upper Elk TMDL.

On September 11, 2008, following the transfer of Palco assets to HRC, the Regional Water Board adopted Order No. R1-2008-0100. This Order transferred all of the standing Regional Water Board Orders from Palco to HRC. Since 2008, HRC has been implementing the HCP developed under Palco management, engaging in timber harvest activities under the WWDRs, and conducting cleanup operations in response to the relevant CAOs.

2.6 Conclusion

The Upper Elk River watershed is located in the temperate rain forest of Humboldt County, California. The climate, hydrology, geomorphology, and geology of the basin interact to create naturally erodible conditions. These naturally erodible conditions, however, are moderated in the Upper Elk River watershed by the mixed coniferous forest, dominated by redwood, which serve to stabilize hillslopes, promote soil development, and produce large woody debris important in metering the delivery of sediment across the landscape and through the aquatic system. Extensive timber harvest activities in the watershed along with a history of regulatory non-compliance have reduced that natural capacity of the Upper Elk River watershed to meter sediment delivery in dynamic equilibrium with the

[30] Order R1-2010-0044 WDRs for Discharges Related to Road Management and Maintenance Activities Conducted Pursuant to the Green Diamond Resource Company Aquatic Habitat Conservation Plan in the North Coast Region.

[31] Order R1-2012-0087 WDR for Discharges Related to Forest Management Activities Conducted Within the Areas Covered by Green Diamond Resource Company Aquatic Habitat Conservation Plan in the North Coast Region.

aquatic system. The result has been severe impacts to the aquatic system and downstream residents from management induced sediment loads and landscape alterations.

CHAPTER 3. Problem Statement for the Upper Elk TMDL

Key Points

- Much of the community of Upper Elk River historically relied upon Elk River for domestic and agricultural water supplies. Due to severe impairment from accelerated discharge of fine grained sediment, many residents currently have no reliable water supply.
- Coho salmon populations in Elk River and its tributaries have been identified as key populations in the *Recovery Strategy of California Coho Salmon* (CDFG 2004). Discharge of management-related fine grained sediment loads continue to impact the salmonid fisheries by increasing instream turbidity and filling pools necessary for rearing.
- Both contact recreation beneficial uses and non-contact recreation beneficial uses, are affected by sediment loads in Upper Elk River.
- The incidence of flooding in the Elk River watershed has increased at an elevated frequency and magnitude due to land use activities and controllable water quality factors. The community of Elk River experiences nuisance conditions as defined by Porter Cologne.

The purpose of the problem statement for the Upper Elk TMDL is to:

- Describe beneficial use impairments, including domestic and agricultural water supplies, cold water salmonid fisheries and recreational uses (Section 3.1).
- Document sediment-related changes in channel and floodplain morphology which explain the increased incidence of flooding and nuisance conditions (Section 3.2).
- Document sediment-related water quality conditions which are unsuitable for the purpose of supporting of salmonid populations (Section 3.3).

3.1 Beneficial Use Impairments

Numerous beneficial use impairments have been documented in the Upper Elk River watershed. These impairments include impacts to domestic and agricultural water supplies, impacts to recreational use of the river, degradation or loss of aquatic habitat, and the creation of nuisance flooding conditions.

To provide background information on the historical use and quality of water in the Upper Elk River, the Natural Resources Services (NRS) staff of the non-profit organization, Redwood Community Action Agency (RCAA), under contract with the Regional Water Board, conducted 14 oral interviews of residents in the Elk River and Freshwater Creek watersheds. The interviews provided anecdotal information from residents about historic conditions in the watersheds. This information was used to help define the historical beneficial uses of water, and the nature and extent of the beneficial use impairment in the Elk River watershed. The results of the interviews are documented in the *Elk River and*

Freshwater Creek TMDL Resident Interviews: Historic Perspectives (RCAA, 2003), included as Appendix 3A. They are also summarized here.

Domestic and Agricultural Water Supplies

Residents of Upper Elk River, including those along the North Fork, South Fork, and Mainstem, have historically relied on surface water intakes in the river for domestic and agricultural water supplies.[32] The majority of water users in Upper Elk River rely on an instream pump intake system, usually placed in a relatively deep and stable pool. As described in Section 2.5 of this Staff Report, in 1997 and 1998 the Regional Water Board issued two Cleanup and Abatement Orders (CAOs); one requiring cleanup of controllable sediment discharges from timber harvest operations in North Fork Elk River, the second requiring the landowner of record (Palco) to provide alternative water systems to residences whose water supplies had been adversely affected by the increased sediment discharges along North Fork Elk River. The CAOs contained findings that verified resident's observations that since 1993, the discharge of sediment associated with controllable land use activities had significant adverse impacts in water quality and stream morphology, including filling of pools historically used for domestic and agricultural water supplies. The CAO also contained findings verifying that the discharge of sediment had resulted in the creation of conditions that produced tastes and odors in water supplies that were offensive to the senses. Further, sediment discharges were found responsible for the increased frequency of maintenance and replacement of hot water heaters and water treatment facilities, as well as damage to agricultural spray equipment and surface water supply intakes. These findings are now well-established.

As described in interviews with affected residents water supplies are impaired by fine sediment in both the winter and summer periods. In the summertime, the availability of suitable pools from which to draw water is limited due to pools being filled with fine sediment. The shallow stream depths and limited summer flows result in the river becoming very stagnant and warm, resulting in taste and odor producing conditions which are offensive to the senses. In the winter time, turbidity levels rise quickly at the onset of a storm and remain elevated following a storm, thus limiting the time period available to withdraw water.

Water used as agricultural supply is appropriate only when turbidity is below 40 nephelometric turbidity units (NTUs) and for domestic use, turbidity must be below 20 NTUs (Pers Comm. Kristi Wrigley, 2008). Historically, after a storm, turbidity levels would subside sufficiently to allow for agricultural and domestic use in 3-5 days. The wait is now substantially longer

[32] In 1981-82, the Humboldt Bay Community Services District (HBCSD) installed a water main on Mainstem Elk River (approximately one-quarter (1/4) mile downstream of Berta Road and approximately 2.5 miles downstream of the Upper Elk River Waterbody. One property owner put up the majority of the capital cost to install this water main (Pers Comm. Micky Holstrom, 2008). Upstream of the service area provided by this water main, residents rely on individual water systems.

In addition to these extended periods of elevated turbidity, the increased turbidity levels also result in excessive fine sediment being entrained in the water supply systems. The fine sediment provides a medium to promote bacteriological growths, thus reducing the effectiveness of water disinfection for domestic water supplies. It also requires more frequent maintenance of filters and cleaning of storage tanks, increasing the cost and difficulty of maintaining these water systems.

Twelve residences of North Fork Elk River received "replacement" water supplies as a result of the 1998 Regional Water Board CAO. The replacement water supplies include the installation of wells for some and river intake/pump systems with filtration and disinfection for others. The operation and maintenance of these systems require much more technical knowledge, more frequent maintenance, and higher expenditures then the residents' previous systems. The CAO is still in effect and HRC, the new owner of record, continues to implement its provisions.

Staff estimates 6 South Fork and 8 Mainstem Elk River residents have also experienced degradation of both groundwater (wells) and instream surface water supplies. Similar water quality conditions as those documented in North Fork watershed are present in South Fork and Mainstem Elk River. No long-term solution for these water users has been established to date and as such these residents do not have a reliable water supply.

Cold Freshwater Habitat

Elk River, a major tributary to Humboldt Bay, provides important freshwater habitat for anadromous salmonids and steelhead. Current habitat conditions are substantially degraded by fine sediment. Stream substrate is very fine, potential spawning gravels are significantly embedded, pool depths have been decreased by sediment filling, and high suspended sediment concentrations and durations affect feeding and rearing behavior.

Numerous sensitive aquatic species, including state and federally listed species, occur in the Upper Elk River and is perennial tributaries. Anadromous salmonids utilizing the watershed include:

- Coho salmon (*Oncorhynchus kisutch*),
- Chinook salmon (*Oncorhynchus tshawytscha*);
- Coastal cutthroat trout (*Oncorhynchus clarki clarki*); and
- Steelhead (*Oncorhynchus mykiss*).

Humboldt Bay tributaries, including Elk River, support some of the last significant populations of wild coho salmon remaining in California (Brown et al. 1994). The California Department of Fish and Game (CDFG)[33] has designated the coho salmon populations in Elk River and its tributaries as key populations in the *Recovery Strategy of California Coho Salmon* (CDFG 2004). Statewide, coho salmon have undergone at least a

[33] In January 2013, the state legislature changed the name of the California Department of Fish and Game (CDFG) to California Department of Fish and Wildlife (CDFW).

70% decline in abundance since the 1960s, and the species abundance is currently at 6% to 15% of the 1940s numbers (CDFG 2004). A summary of fisheries observations in provided in Appendix 3-B. As assessment of the water quality data, as it relates to salmonid habitat and health, is presented in Section 3.4.

Contact and Non-Contact Recreation

Both contact recreation beneficial uses, including swimming, wading, and fishing and non-contact recreation beneficial uses, including picnicking, hiking, camping, boating, and aesthetic enjoyment are affected by sediment loads in Upper Elk River.

Contact recreational uses in the Upper Elk River are impaired, in part, due to the lack of deep pools, resulting from sediment deposits and the accumulation of small wood debris and branches and other shrubby vegetation that has encroached on the channel in response to the altered geomorphology. The channel bottom has also been covered with a substantial layer of silt-sized material, rather than sand and gravel sized material, making wading and swimming unpleasant. The anaerobic condition of water during summer months and the presence of aquatic vegetation, such as duckweed, also impairs the use of water for contact recreational purposes.

Non-contact recreational uses, including boating and aesthetic enjoyment, is also limited due to the nature and extent of the sediment impairment. Boating is difficult due to lack of stream depth and the accumulation of small vegetative debris, while aesthetic enjoyment is limited due to the degraded stream and riparian conditions and noxious odors arising from shallow, stagnant water and algae growths.

An assessment of water quality data in Section 3.4 demonstrates the change in channel conditions which have resulted in impairment of recreational enjoyment and use in the Elk River watershed.

Nuisance Flooding

Discharges of waste sediment and organic debris to watercourses have aggraded the stream channels in the low gradient reaches of Elk River, significantly reducing channel capacity. The incidence of flooding in the Elk River watershed has increased at an elevated frequency and magnitude due to land use activities and controllable water quality factors. Fields, roadways, driveways, homes and septic systems are frequently inundated. The community of Elk River experiences nuisance conditions as defined by Porter Cologne.

Potentially serious impacts to health and safety are associated with these flood events, as residents attempt to cross flood waters, as emergency vehicles are limited from accessing homes, and as power can be lost to people dependent on health-support machinery and other people for care. Additionally health impacts from contaminated flood water entering a home include damage to walls, flooring, furniture, etc. and the potential for growth of harmful molds in homes. The frequency of flooding events in the Elk River watershed has led to increased costs to landowners and a general lack of well-being to residents of the Elk

River community. Examples of nuisance flooding conditions in the community of Elk River are depicted in Figures 3.1 and 3.2.

Overbank floods now occur at a frequency of 4 times per year on North Fork Elk River (Regional Water Board, 2005). As a consequence there is flooding of roads, fields, fences, and homes at intervals that are much more frequent than occurred historically. This affects the livelihoods of those who live in the community of Elk River. South Fork and Mainstem also flood, though their frequency of occurrence is not as readily quantifiable as on North Fork (Regional Water Board staff, 2005).

The Regional Water Board received a petition on October 2, 2004, signed by 64 Elk River residents, requesting, in part, that the Regional Water Board issue a CAO to Palco (the landowner of record), requiring dredging of sediment deposits in North Fork, South Fork and Mainstem Elk River to abate the nuisance flooding conditions and recover beneficial uses of water. In 1998, the Regional Water Board staff found that the potential environmental impacts from the removal of the sediment deposits were too great given the state of knowledge in the watershed. The Regional Water Board denied the residents' petition[34] to initiate dredging on the basis that a feasibility study and the identification of a viable lead entity were necessary prior to initiating such an effort.

As a result of the development of the Upper Elk TMDL and related restoration actions in the watershed, the Regional Water Board has sufficient information to conclude that removal of instream sediment and other remediation efforts are in fact fundamentally necessary to the timely recovery of the beneficial uses of water in this watershed and abatement of flooding conditions (see Appendix 3-C). An assessment of the quantity, fate and transport of instream stored sediment and the feasibility of its remediation will be developed as part of *The Elk River Watershed Recovery Assessment and Pilot Sediment Remediation Project*, to be managed by CalTrout as the lead entity.

[34] Order No. R1-2004-0042, Declining Request for Order Requiring Dredging in the Elk River.

Figure 3.1 Lower North Fork Elk River during Dec 29, 2003 flood (photo part of Regional Water Board public files.)

Figure 3.2 Upper Mainstem Elk River at Elk River Courts, located at the downstream extent of the Upper Elk River Waterbody. (Photo courtesy of Humboldt County Public Works Dept, taken February 18, 2004).

3.2 Sediment Data Collection and Analysis in Upper Elk River

This section describes the monitoring efforts undertaken in the Upper Elk River watershed. Analysis of the data with respect to changes to stream channel morphology and floodplain conditions is provided in Section 3.3. Analysis of the data relevant to salmonid habitat quality and salmonid health is provided in Section 3.4.

Over the past 15 years, various stakeholder groups have been conducting instream water quality monitoring and channel form evaluations at a number of locations in the Elk River watershed (Figures 3.3 and 3.4 and Table 3.1). Monitoring efforts undertaken by industrial landowners, residential landowners, and others such as the fisheries advocacy group, Salmon Forever, have verified the impaired nature of the beneficial uses of water in the watershed and provided data to support the development of the Upper Elk TMDL.

Palco began trend monitoring under a CWC section 13267(b) Order of the Regional Water Board in 1997. The trends monitoring network established under the order was subsequently expanded to satisfy the requirements of the Palco HCP. In response to a 2001 State Water Board Order[35], Palco began collecting turbidity, suspended sediment, and streamflow data in an attempt to quantify the water quality impacts from a specific, proposed timber harvest operation located in South Fork Elk River.[36] In 2003, the Regional Water Board[37] required Palco to expand the monitoring network to more comprehensively measure suspended sediment in the watershed. The order required submittal of water quality data to support TMDL development, including stage, streamflow, turbidity, and suspended sediment data. Currently, HRC maintains the network of stream gages and submits annual data reports to the Regional Water Board.[38]

[36] THP 1-97-520 HUM.
[37] MRP Order No. R1-2002-0088.
[38] MRP Order No. R1-2006-0039.

Salmon Forever began collecting suspended sediment and turbidity grab samples and stream discharge measurements in the Elk River in 1999. In 2003, they installed turbidity threshold sampling (TTS) stations and began continuous data collections in lower North Fork and lower South Fork Elk River. Salmon Forever also established stream cross-sections associated with these stations. The Salmon Forever monitoring efforts have largely utilized trained volunteers. In 2004, RCAA received a grant from the State Water Board[39]that helped to support the monitoring efforts. In 2007, RCAA received a second State Water Board grant which further supported Salmon Forever's monitoring and data processing efforts.[40]

In 2001, GDRC installed a TTS station in McCloud Creek under a cooperative agreement with the Regional Water Board.[41] This station was operated for hydrologic year (HY) 2003. In HY 2006, GDRC reinstalled the monitoring station under order of the Regional Water Board.[42]

In water year 2004, under contract with the Regional Water Board and in coordination with Palco and BLM, Humboldt State University installed a TTS station in Upper Little South Fork Elk River, Corrigan Creek, and South Branch North Fork Elk River. These subbasins are described in Appendix 4-C as they provided the basis for comparing reference and managed conditions in Upper Elk River (Manka, 2005). Monitoring at those stations has been ongoing by HRC.

In addition, void monitoring associated with excavation work to treat controllable sediment discharge sites has been conducted by Palco, GDRC, and BLM. Void monitoring quantifies the volume of sediment discharged following cleanup of controllable sediment discharge sites.

Much of the TMDL analyses are dependent on the monitoring data generated by the hard work of these various dedicated groups.

[39] State Water Board Agreement Number 03-212-551-0, Humboldt Bay Water Quality Improvement Program: Water Quality Monitoring and NPS Pollution Education.
[40] State Water Board Agreement Number 06-289-551-0, Humboldt Bay Watershed Sediment Reduction, Monitoring and Salmon Habitat Implementation Program.
[41] Cooperative Agreement, September 24, 2002, MRP for Simpson Timber Company, Elk River, Humboldt County.
[42] MRP Order No. R1-2006-0043.

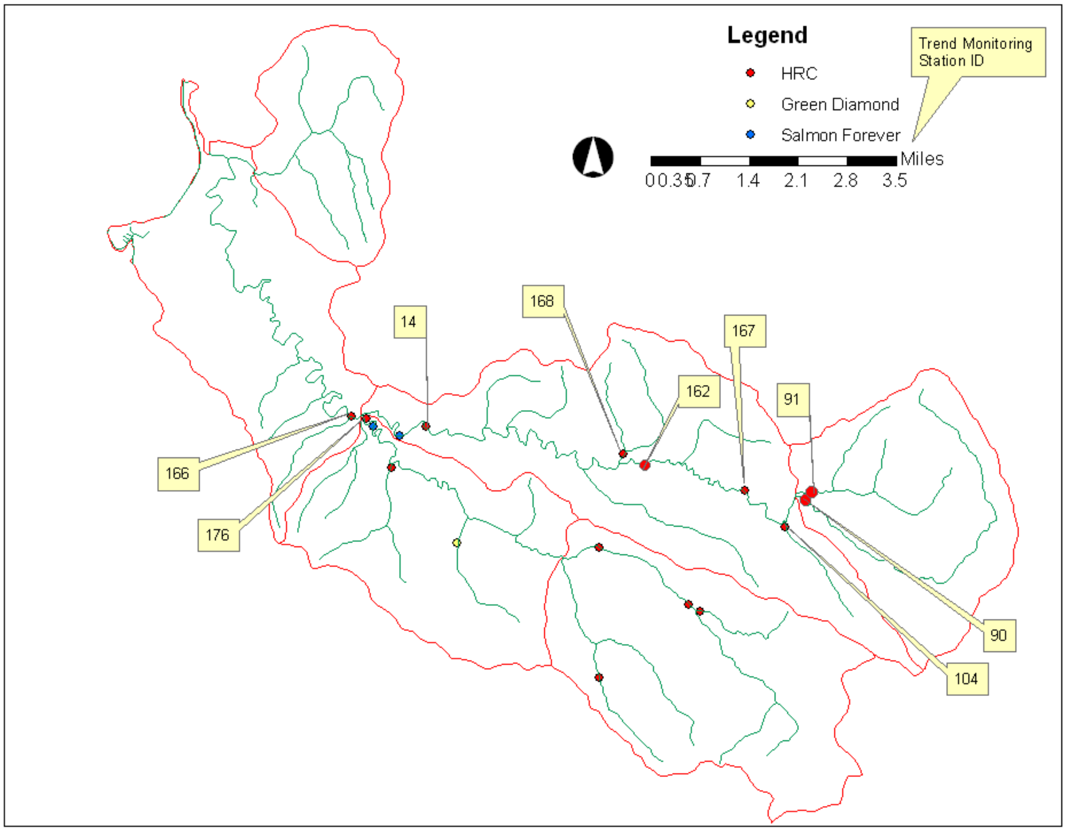


Figure 3.3 Locations of select instream monitoring stations in Elk River (dots represent locations of turbidity, suspended sediment concentration, stage and streamflow collection and numbered locations represent HRC aquatic trend monitoring stations) (Regional Water Board, 2008).

Table 3.1 HRC (formerly Palco) aquatic trend monitoring station number and location.

Station Number	Location
90	North Fork Elk River
91	North Branch Elk River
104	South Branch North Fork Elk River
167	North Fork Elk River
162	North Fork Elk River
168	Bridge Creek
14	North Fork Elk River
175	South Fork Elk River
166	Mainstem Elk River
214	North Fork Elk River
217	South Fork Elk River

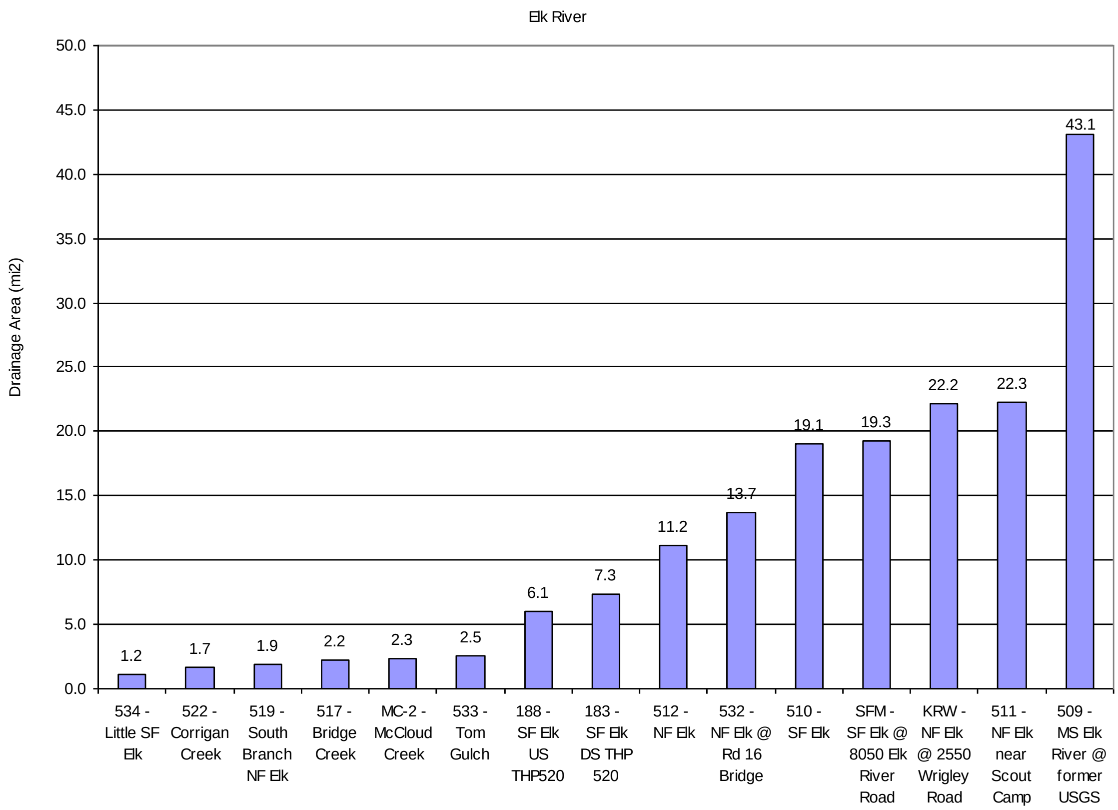


Figure 3.4 Turbidity, suspended sediment and streamflow monitoring station identification, location, and associated drainage area (square miles).

3.3 Altered Channel and Floodplain Morphology

Morphologic changes resulting from deposition of fine sediment is described based upon observations by residents and staff and corroborated with cross-sectional surveys.

The sediment supply in Upper Elk River has overwhelmed the transport capacity of the river resulting in rapid channel and floodplain aggradation. Deep pools and gravel bars have been filled in and silted over, respectively. The naturally steep stream banks and low terraced floodplains that defined the former bankfull channel have been inundated with repeated deposition of excessive amounts of very fine sand and silt-sized sediment. The broader floodplain is also routinely covered in silty deposits during overbank flooding events.

Figure 3.5 Resident Kristi Wrigley at her family's 100-yr old North Fork Elk River apple orchard indicating the height above the ground surface that the apple tree branches spread from the trunk. The 2.5 foot tall trunk is now buried in sediment. (Photo by RCAA NRS staff, December 16, 2003)

Figure 3.6 Fence post on North Fork Elk River buried approximately 4 foot in sediment (Photo by Adona White, 2008).

Evidence of excessive sediment deposition on the floodplain includes burial of fence posts in up to 4 feet of sediment (Figure 3.5) and burial and loss of 100 year old apple trees in the North Fork Elk (Figure 3.4).The majority of this deposition occurred during the period of 1993 to 1998 when large volumes of sediment were delivered to the watercourses from the landslide events triggered during those years. Interviews with residents and land managers in the Elk River indicate that observable changes in channel structure began around 1987 (RCAA NRS, 2003) and by 1993 significant changes in water quality were noticeable (Dudik, 1998).

The extent of changes in channel bed elevation was explored by Regional Water Board staff (Patenaude, 2004) via a comparison of stream gage records from USGS and Palco. Specifically, the channel capacity as a function of cross-sectional area was estimated from the USGS data. The changes in cross-sectional area are summarized in Table 3.2 for hydrologic years (HY) 1958, 1959, and 1965. These data indicate that there was not a significant change in cross-sectional area as a result of the 1964 event; an important finding considering that 1964 was one of the most well-known channel-altering events on modern record in the north coast and should reflect the Upper Elk River watershed's response to significant rainfall on a post-1940's (advent of large scale ground based yarding equipment) landscape. Comparison of the Palco collected data to the USGS data indicates the 2003 channel capacity is 400 square feet (ft^2) less than the 1965 historic channel capacity (decreased by at least 35%) (Table 2.3).

Table 3.2 Estimated Channel Capacity of Elk River at Gage Station (based on USGS records (Patenaude, 2004)

Water Year	Cross Sectional Area (ft^2)
1958	1180
1959	1163
1965	1158
2003	758

The recent streamflow records indicate that velocities in the depositional reaches of Upper Elk River are fairly low, considering the flow rates. The fine sediment coating the stream bed and banks, along with low velocities, and lack of habitat complexity, and high suspended sediment loads combine in a manner that perpetuates the degraded conditions. The consequence is a sluggish system which readily deposits sediment, cannot scour the stored sediment, and does not readily drain during high flow events, causing numerous overbank events. The overbank flows spread over large areas in the broad valley and deposit sediment. As a result the floodplain and associated overbank berms are also building at a high rate.

Persisting sediment loads, in combination with sluggish hydraulics, and sediment properties have combined to leave fine grained settable sediment in place, resulting in an elevated channel base level. Channel armoring is ongoing with both sediment particles and vegetation further locking in an elevated base level. Channel cross-sections continue to be reduced due to sediment deposits.

A further confounding factor is the occurrence of bank slumps within the current flood-prone reach. The bank slumps were first observed as relatively small and discrete features. However since 2002, numerous bank slumps features have formed as the relatively fresh sediment deposits on the banks are not sufficiently stable to withstand the hydraulics of the stream system. However, bank slumps also extend into native material (Figure 3.7). The relatively small sized riparian vegetation, comprised primarily of willow and red alder, enter the channel along with the bank slump material.

Further, the freshly deposited sediment on the banks is readily colonized by the invasive non-native Himalaya blackberry. Recently, observations indicate that channel deposits are also being colonized by grass species, armoring the elevated channel bed (Figure 3.8). The consequence is that the in-channel vegetative roughness elements further influence the low velocities in the system. This relationship further limits the scouring capability of the system to efficiently pass streamflow and suspended sediment.

Figure 3.7 Bank slump on Upper Mainstem Elk River (Photo by Nancy Sievert, 2003).

Figure 3.8 Grass colonizing channel on lower North Fork Elk River near the confluence with South Fork (Photo by Adona White, 2008)

In 1998 Palco (then HRC in 2008), began surveying cross-sections at the aquatic trend monitoring (ATM) sites established in Elk River. See Figure 3.3 and Table 3.1 for locations of ATM sites (shown as numbered locations). Figures 3.9 through 3.13 indicate the magnitude of change in cross-sectional area (ft^2) within the depositional reaches of Upper Elk River (negative values indicate filling, positive values indicate scour). This cross-sectional data generally demonstrate ongoing deposition.

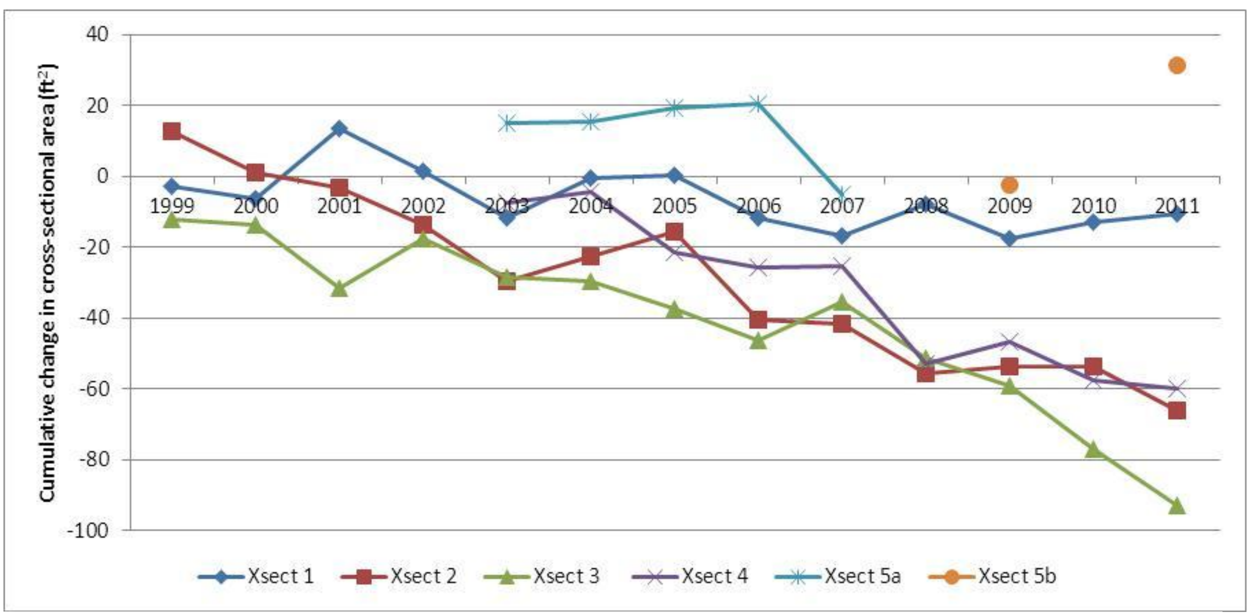


Figure 3.9 Cumulative change in cross-sectional area 1998-2011 at ATM Station 166 (located on upper Mainstem Elk River within reach formerly gaged by USGS).

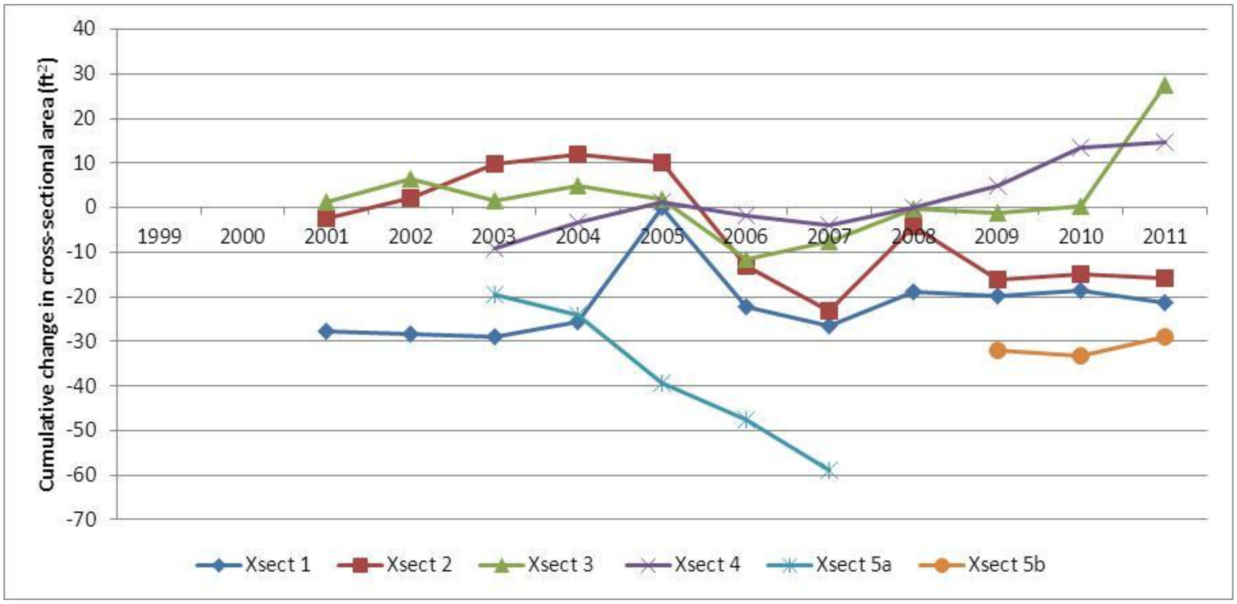


Figure 3.10 Cumulative change in cross-sectional area 2000-2011 at ATM Station 175 (located on lower South Fork Elk River).

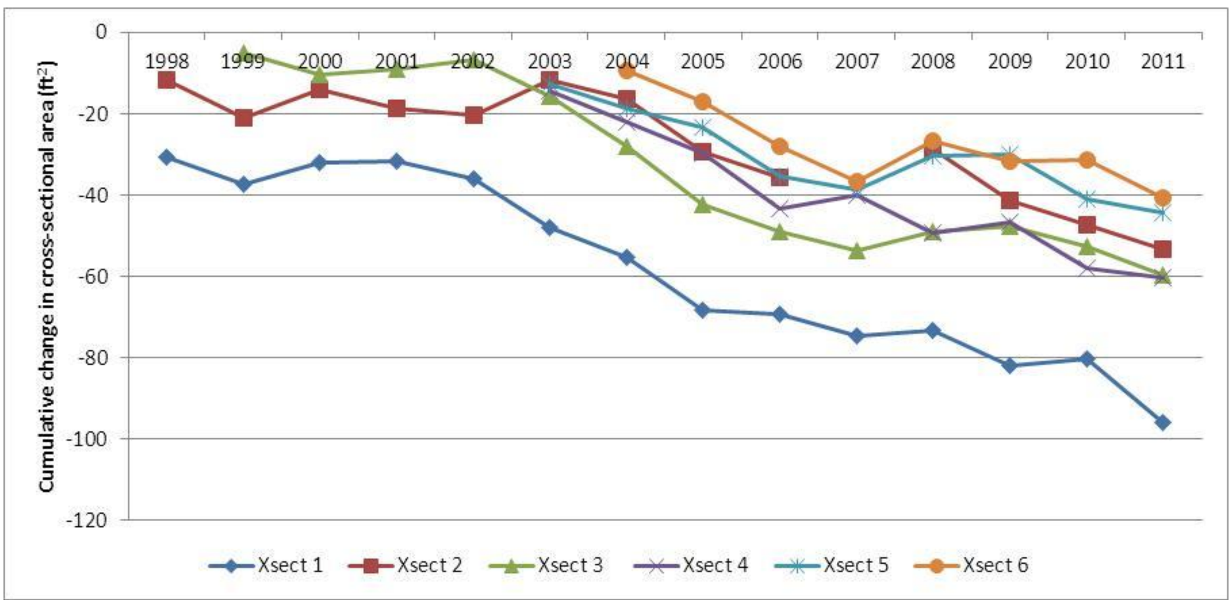


Figure 3.11 Cumulative change in cross-sectional area 1997-2011 at ATM Station 14 (located on lower North Fork Elk River).

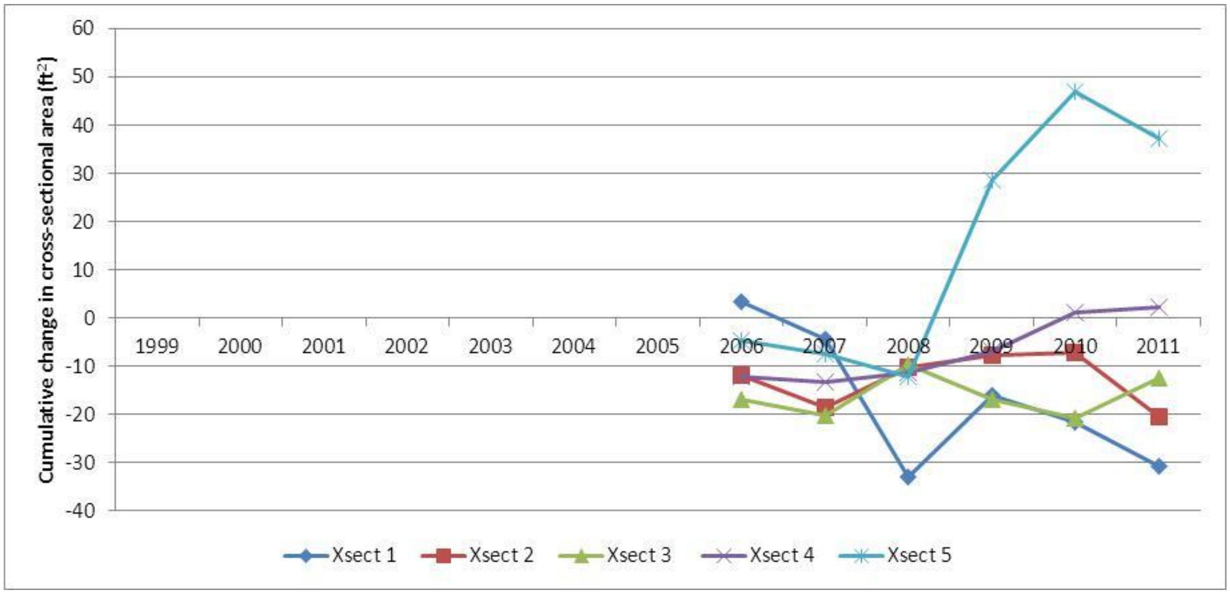


Figure 3.12 Cumulative change in cross-sectional area 2005-2011 at ATM Station 162 (located on North Fork Elk River upstream of Bridge Creek).

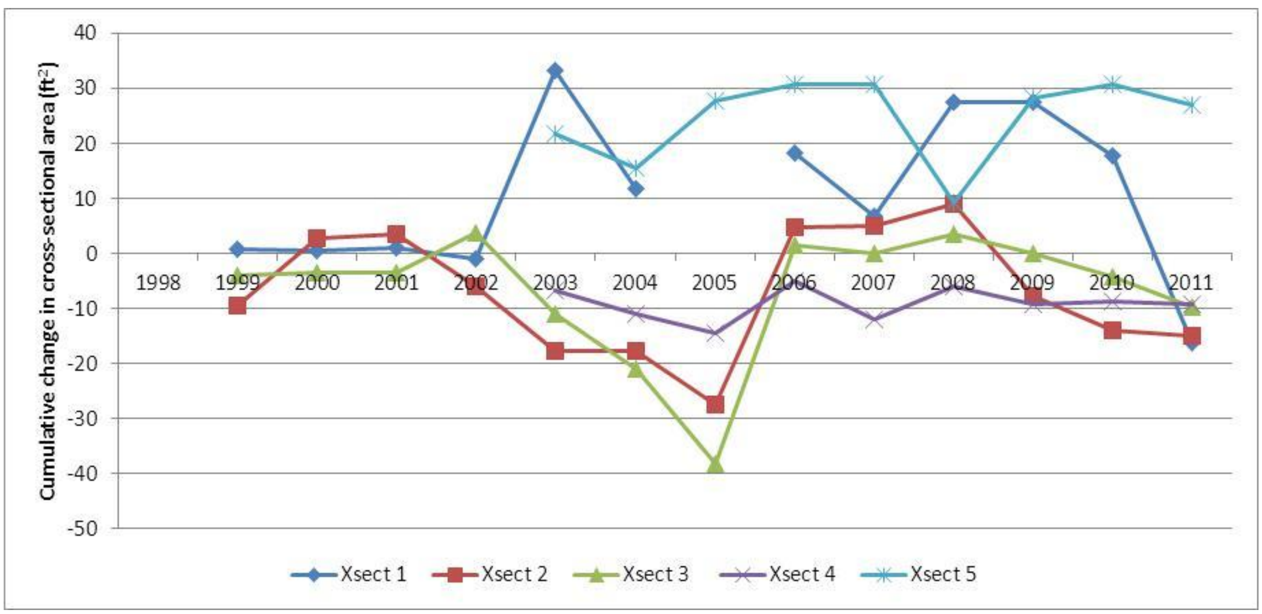


Figure 3.13 Cumulative change in cross-sectional area 1998-2011 at ATM Station 214 (located on lower North Fork Elk River at Scout Camp).

In 2002, Salmon Forever established a network of stream cross-section stations in the vicinity of the confluence of North Fork and South Fork of Elk River (Figure 3.14). The cumulative change in cross-sectional area of the active channel for Mainstem, North Fork, and South Fork Elk River are shown in Figure 3.15, 3.16, and 3.17, respectively (negative values indicate filling, positive values indicate scour). The Salmon Forever cross-sections demonstrate a general pattern of channel filling between 2001 and 2008 (Salmon Forever, 2011). Additionally, staff evaluated the Salmon Forever cross-sections to determine the depth of sediment deposition and scour on the channel bed, banks, and floodplain areas (Figure 3.18).

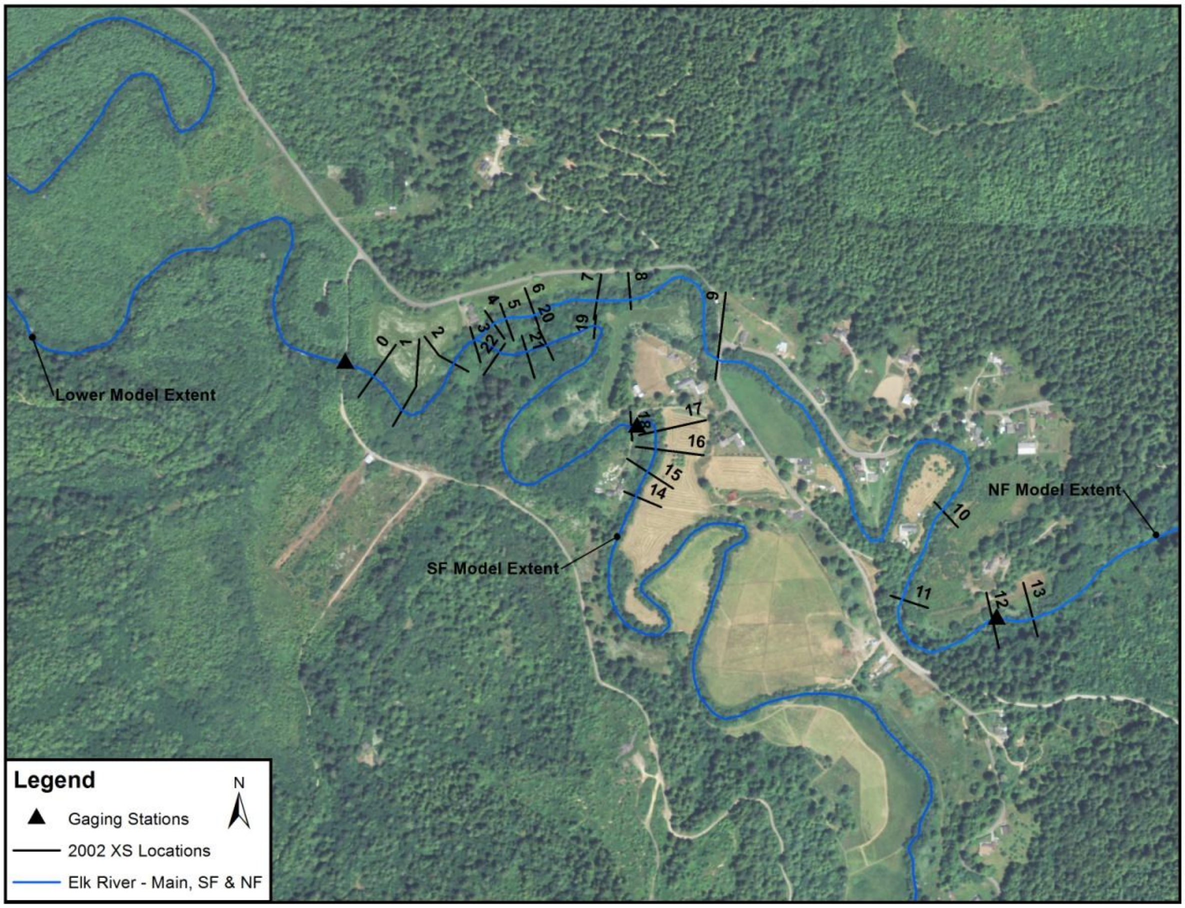


Figure 3.14 Location of Salmon Forever cross-sections near the confluence of the North and South Forks of the Elk River (NHE, 2012).

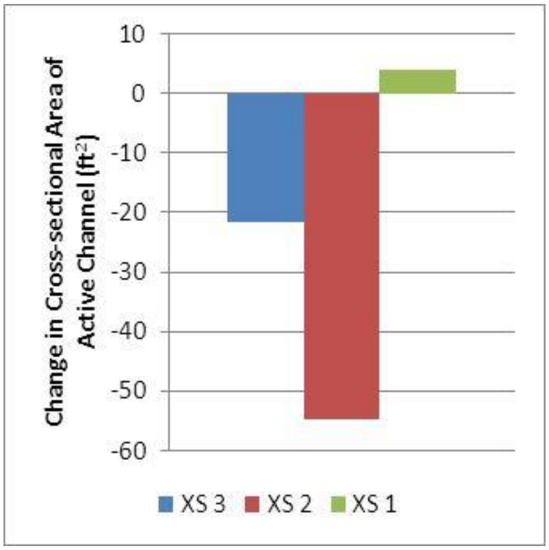


Figure 3.15 Cumulative change in cross-sectional area of active channel on Mainstem Elk River (Salmon Forever, 2001-2008).

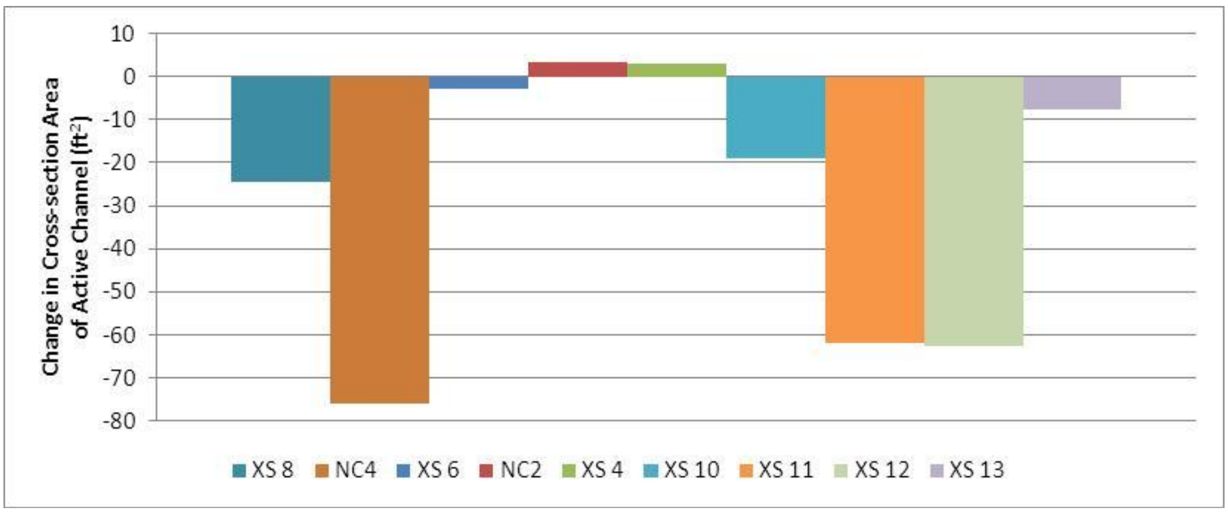


Figure 3.16 Cumulative change in cross-sectional area of active channel on North Fork Elk River (Salmon Forever, 2001-2008).

Figure 3.17 Cumulative change in cross-sectional area of active channel on South Fork Elk River (Salmon Forever, 2001-2008).

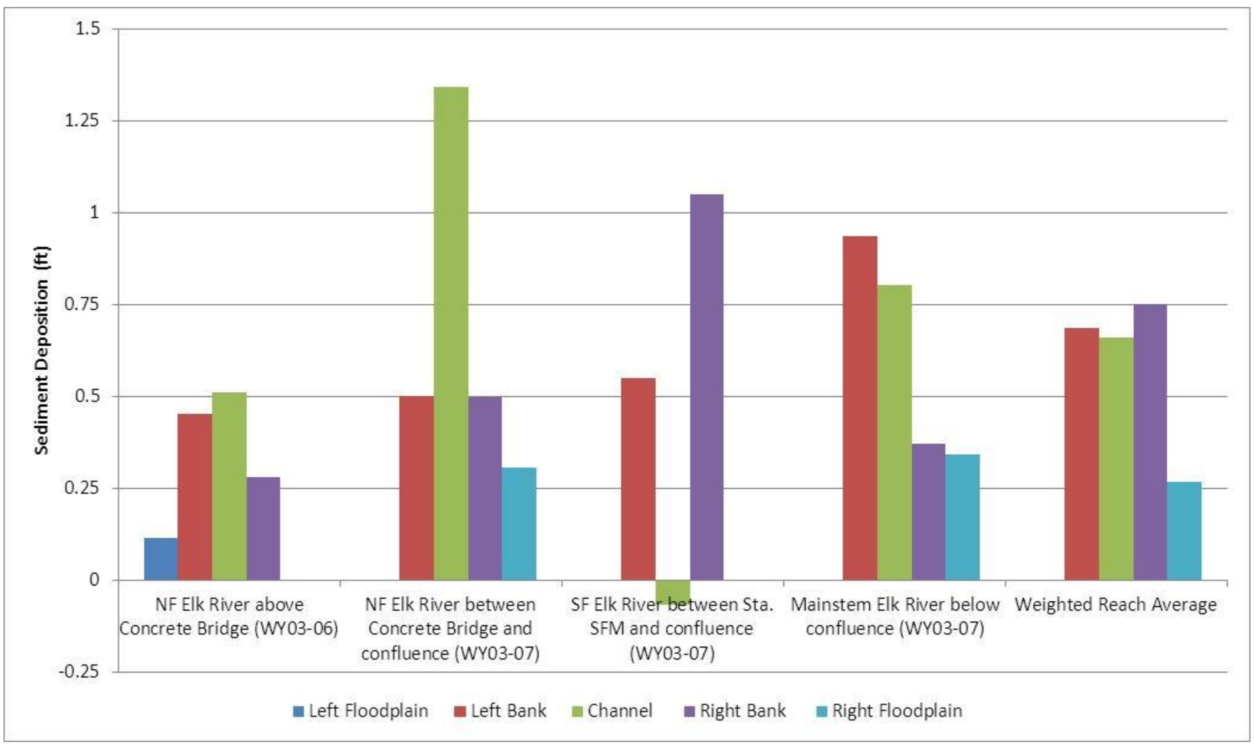


Figure 3.18 Measured deposition at cross-sections on right and left floodplain and banks (left as observed facing downstream) and channel bed (Salmon Forever 2003-2007).

Estimating the volume of the stored instream deposits is subject to uncertainty as the deposits have yet to be thoroughly characterized in terms of both their longitudinal and lateral depths. Such characterization is likely to be part of any recovery assessment and restoration planning effort. However, as part of the development of the TMDL, a volume estimate was developed using the lines of information presented in this section. Table 3.3

presents estimated volume of stored material in different segments of the storage reach of Elk River. There is uncertainty associated with these estimates, including variations in the depth of the sediment deposits and channel dimensions between measured cross-sections. Further uncertainty results from the fact that the cross-sectional measurements do not encompass the entire bank or the floodplain, the original channel dimensions are indiscernible under the deposits and the volume of the deposits continue to increase within the middle reach. The Upper Elk TMDL assumes the estimates provided in Table 3.3 offer minimum volumes of instream sediment deposits. This is because the affected reaches are likely much longer than the length used to develop the estimate and the sediment loads from the entire bank and floodplains were not included in the calculations.

Table 3.3 Estimated volume of instream deposits within the storage reaches of Upper Elk River.

Reach description (downstream to upstream)	Drainage area (mi^2)	Reach Length (mi)	Basis for Cross-Section Dimensions	Bed Deposition (ft)		Bank Deposition (ft)		Area of Deposition within Cross-Section (ft^2)	Volume Deposition within Reach (yd^3)	Volume Deposition per Unit Area (yd^3/mi^2)
				Width	Depth	Slope Distance[43]	Depth			
Upper Mainstem: Shaw Gulch to confluence	**45.23**	**3.05**	**Mean**	**27**	**5**	**27**	**5**	**435**	**259,428**	**5,736**
			Salmon Forever	16		16		372		
			HRC ATM 166	31		31		439		
			USGS	35		35		495		
Lower North Fork: confluence to Browns Gulch	**22.02**	**3.77**	**Mean**	**23**	**5**	**23**	**5**	**381**	**280,948**	**12,759**
			Salmon Forever (upstream of bridge)	21		21		409		
			Salmon Forever (downstream of bridge)	19		19		434		
			HRC ATM 14	31		31		299		
Lower South Fork: confluence to Toms Gulch	**19.46**	**1.87**	**Mean**	**17**	**4**	**17**	**4**	**269**	**98,163**	**5,044**
			HRC ATM 175	21		21	4	205		
			Salmon Forever (SB)	13		13	4	333		

[43] Slope distance was calculated as: *Slope Distance = √((Horizontal Distance)^2+(Channel Depth)^2).*

3.4 Water Quality Conditions Affecting Salmonids

Several different data and methods of analysis were used to evaluate the degree to which water quality conditions in the Upper Elk River watershed are suitable for salmonids. Bulk sediment samples were collected and analyzed to assess bed composition, including the percent of the substrate which is comprised of fine material, as well as the distribution of particle sizes. Residual pool depth was measured over time at a number of locations to assess rearing habitat availability. Suspended sediment data were compared to a Severity of Ill Effects index to determine the potential for impact to salmonids. Finally, turbidity rating curves were developed for two managed subbasins and compared to a reference subbasin to determine the degree to which elevated fine sediment loading from managed subbasins differs from background conditions, This analysis was conducted to determine the degree to which land management activities can be said to be responsible for elevated fine sediment loading in the Upper Elk River watershed and the impairments noted.

Bed Composition

Channel bed material is sampled for various purposes, including as a measure of gravel suitability for spawning salmonids and other aquatic organisms. In addition, these data can be used for inputs into sediment transport models, as they are indicative of a river's overall stability, including its ability to transport its sediment supply. Channel substrate material is collected in bulk using shovel samples and sieved to determine the percent of the bed comprised of diameters less than a particular sieve size.

A grain size of 0.85 mm is indicative of coarse sand; particles finer than 0.85 mm can smother gravels, thus entombing fish eggs and aquatic insects. Figure 3.19 shows percent fines greater than 0.85 mm as measured at 11 Elk River stations (see Figure 3.3 and Table 3.1 for station locations). In 2006, 43% of the stations met the instream desired condition of greater than 14% for particles less than 0.85 mm. 57% of the stations demonstrated improvement (tending towards coarser particle sizes) as compared to the previous year, with 43% of the stations becoming finer grained. None of the stations demonstrated steady trends of improvement over the period of record.

A grain size of 6.35 mm is considered fine gravel. Particles less than this size can mobilize with relative ease during normal streamflow regimes. Figure 3.20 shows percent fines less than 6.35 mm for Elk River stations. Twenty-nine percent (29%) of the stations measured in 2009 met the instream desired condition of greater than 30% for this parameter. Only Station 90 indicated a steady trend towards a larger grain size substrate. This trend was documented until 2004 when the station was dropped from the monitoring network. Stations 214 and 217 were first measured in 2005 and have approached or achieved the target since then.

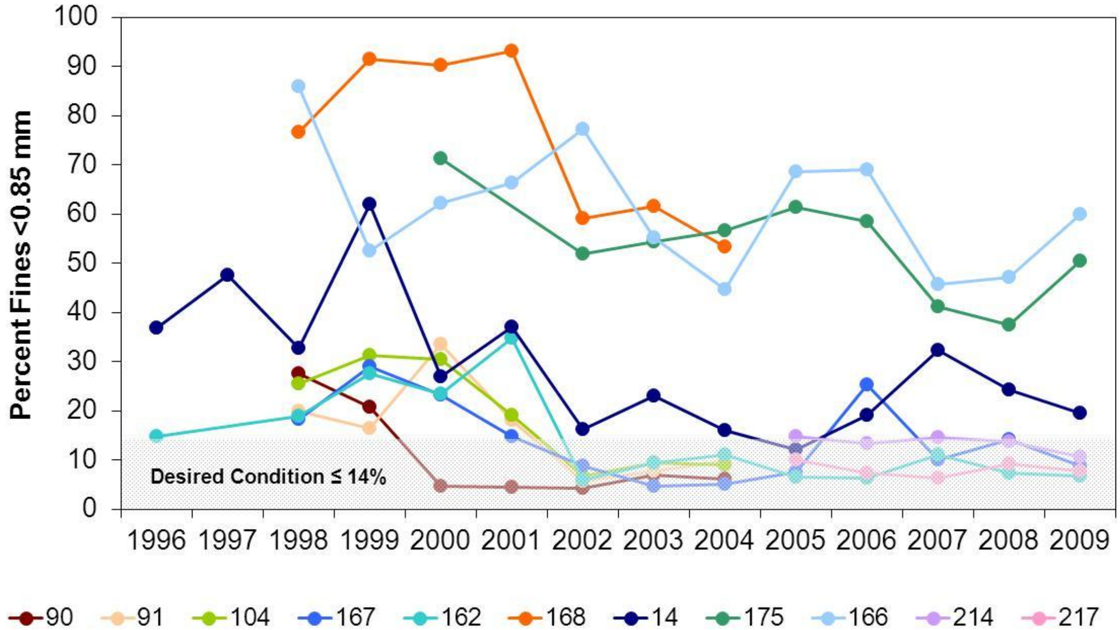


Figure 3.19 Percent fines <0.85 mm in Elk River (HRC ATM sites).

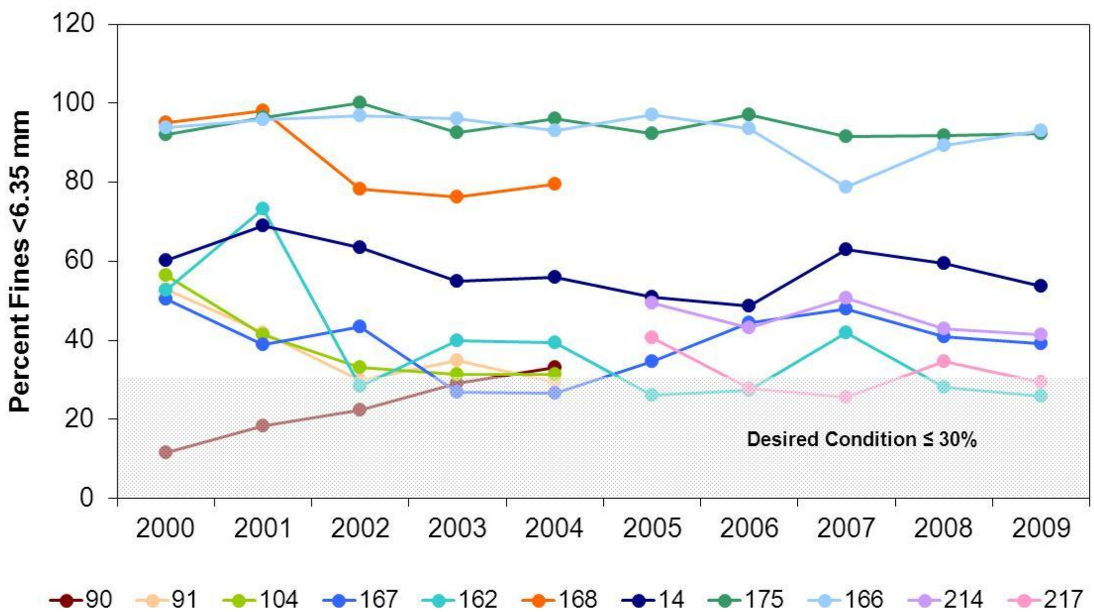


Figure 3.20 Percent fines <6.35 mm in Upper Elk River (HRC ATM sites).

In 2011, RCAA contracted with the firms, Northern Hydrology and Engineering (NHE) and Stillwater Sciences (Stillwater), to develop and apply a predictive hydrodynamic and sediment transport (HST) modeling approach in a pilot reach of the middle Elk River (Figure 3.21). The final report describing the effort is included as Appendix 3-D. Sediment samples were collected as part of the pilot modeling (Figures 3.22 and 3.23), indicating the majority of the bed is comprised of very fine sand and silt and the channel banks and floodplain are comprised of silty sand.

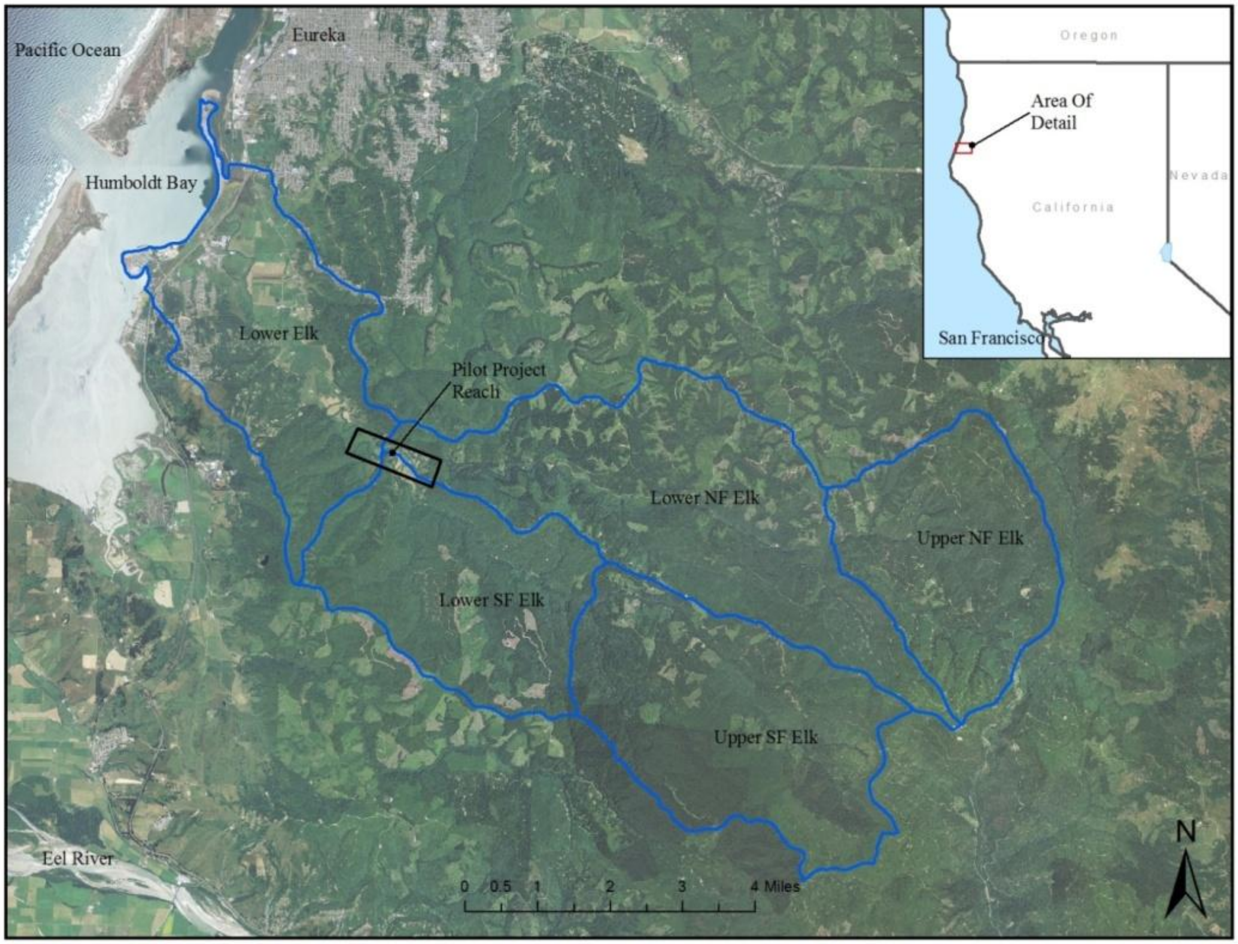


Figure 3.21 Hydrodynamic and sediment transport pilot modeling reach, Upper Elk River (NHE, 2012).

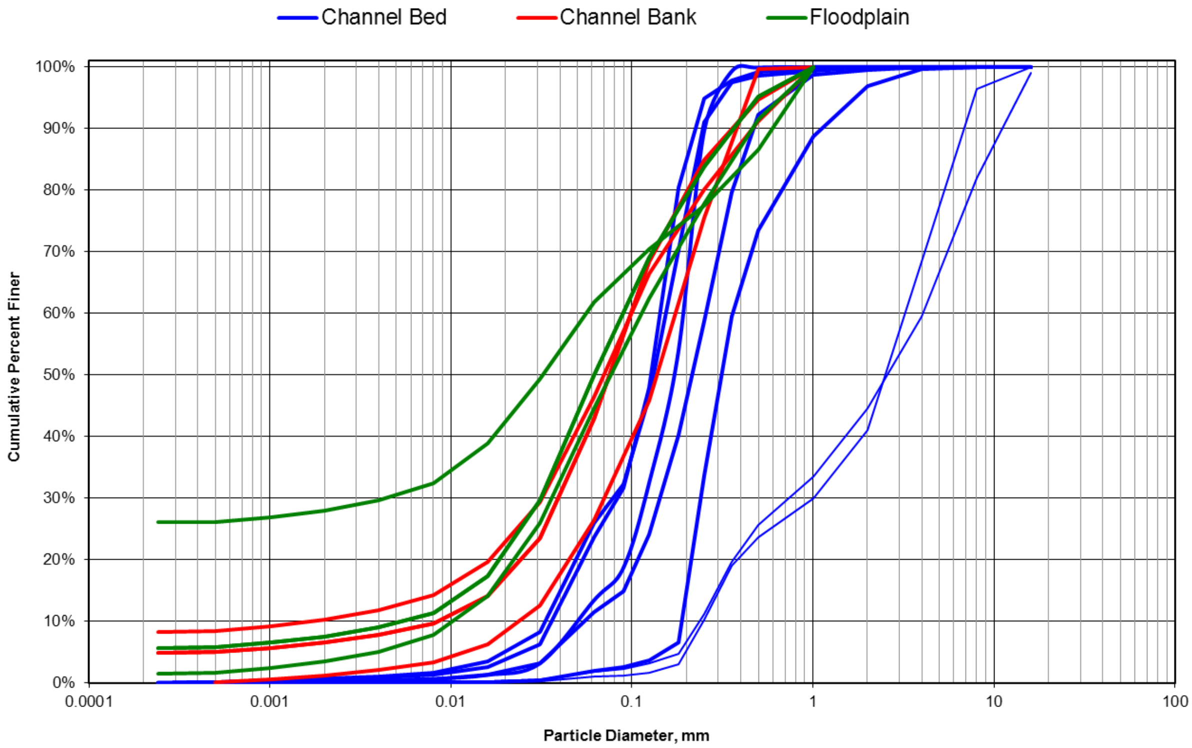
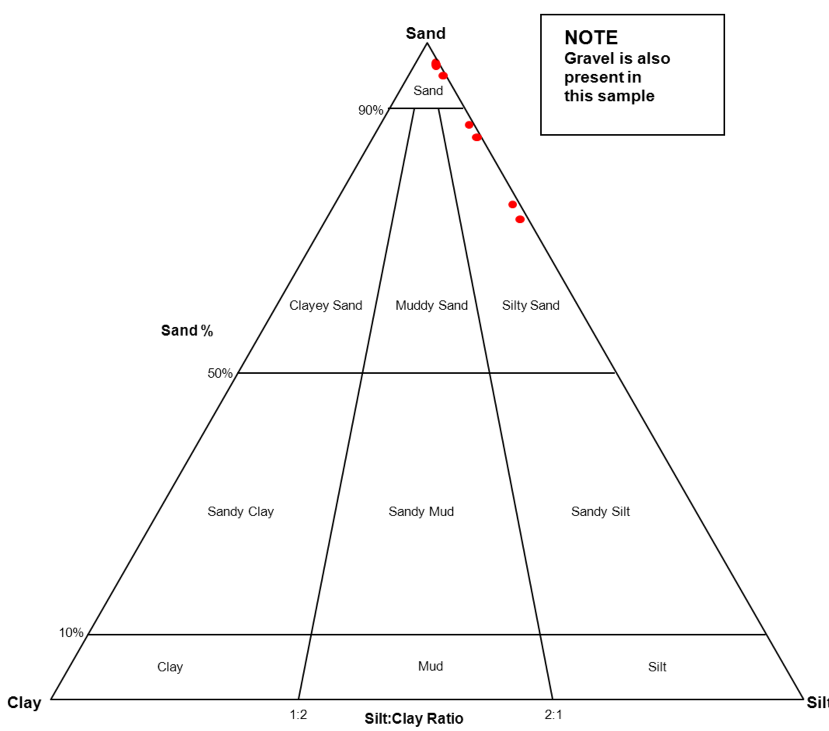
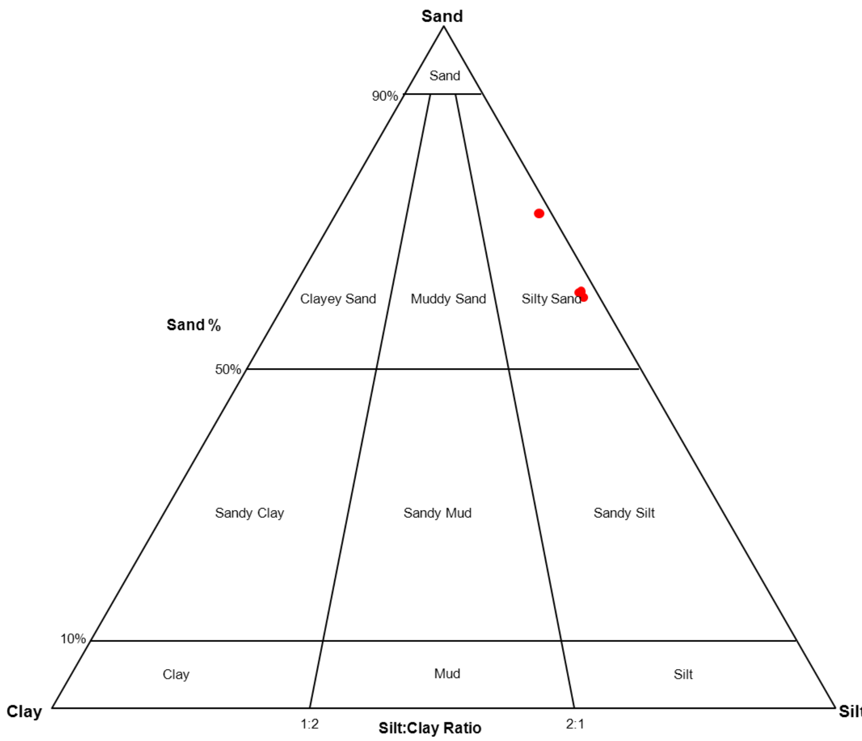


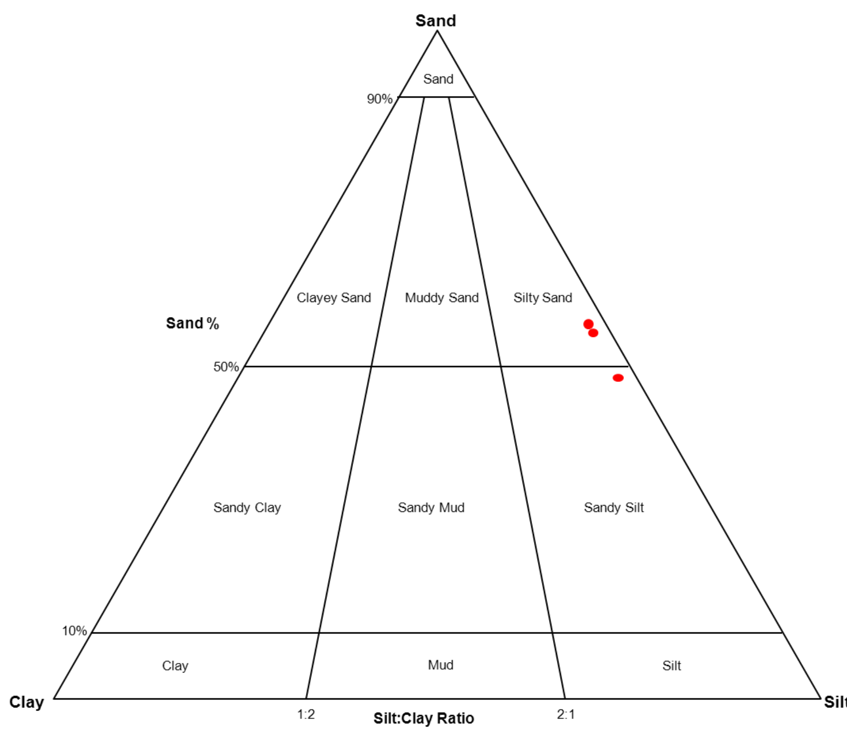
Figure 3.22 Particle size distributions of bulk samples from channel bed, channel bank and floodplain sediment deposits.



A) Channel bed deposits



B) Channel bank deposits



C) Floodplain deposits

Figure 3.23 Sand-silt-clay diagrams for bulk sediment samples of A) channel bed, B) channel bank, and C) floodplain deposits.

Channel Bed Surface Composition

D_{50} is a measure of the particle size distribution of the surface of a streambed, specifically the particle size for which 50% of the sample has a diameter smaller than the D_{50} value. The channel bed surface layer is typically coarser than the underlying layers as fines are more readily winnowed away by streamflow. Characterization of the channel material is a useful tool for evaluating biological function and channel stability. In some cases, the surface layer can act as an armor layer, if it persists through transport events. As of HRC's 2009 annual monitoring report, 100% of the measured stations did not meet the desired condition of 65-95 millimeters (mm). In 2000-2001, only Station 166 (located in the upper portion of the watershed) met the desired condition. Otherwise, none of the stations met the desired condition for all other years reported (Figure 3.24).

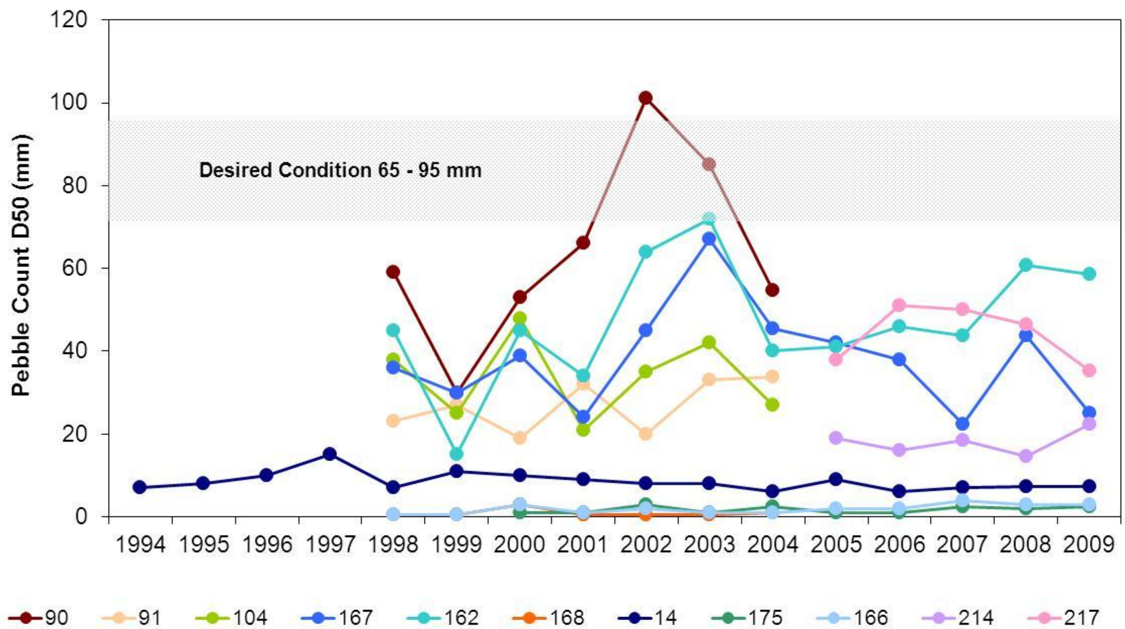


Figure 3.24 Pebble count D_{50} conditions in Upper Elk River (HRC).

Pool Conditions

Pools of 3-feet and greater have been identified as critical for salmonid fisheries, especially for coho salmon habitat. Deep pools are necessary to meet temperature needs of salmonids as well as provide cover from predation. Generally, pool depths in the trend monitoring reaches do not fully support cold water fisheries habitat. As described above, many residents have historically relied on surface water intakes for domestic and agricultural water supply. For this purpose, too, adequate pool depth in the Elk River is necessary. Low pool depths are indicative of aggraded channel conditions. Over the period of record, pool depths have fluctuated slightly, only one station in Upper Elk River (station 214) barely met the desired condition of 3-feet or greater (Figure 3.25). It should be noted that the data presented do not indicate the depth of pools prior to the major sediment impacts that took place in the late 1990's as a result of land management and large landslide-triggering storm events.

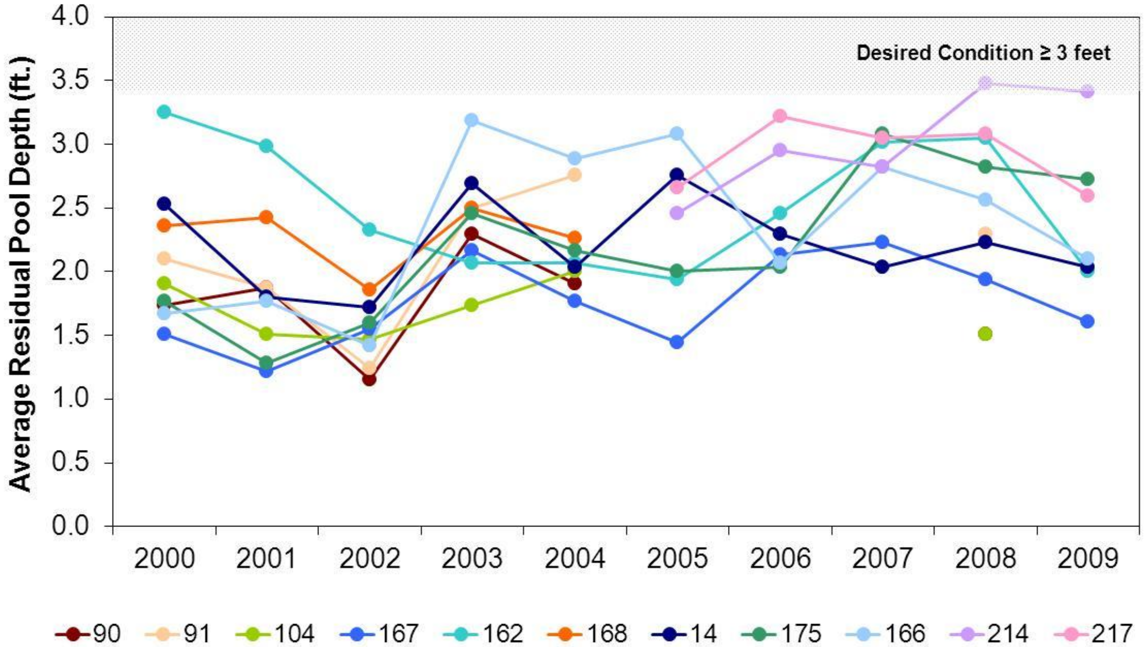


Figure 3.25 Average residual pool depths in Elk River (HRC).

Suspended Sediment Impacts to Fish

Suspended sediment concentrations and duration appear to have significant effects on salmonid feeding and rearing patterns. Using a model developed by Newcombe and Jensen (1996), staff evaluated the monitoring data collected in Upper Elk River to develop predictions of the relative magnitude of ill effects on salmonids resulting from the measured suspended sediment and turbidity concentrations. Further details of the analysis are contained in Appendix 3-E.

Using 80 studies documenting the effects of suspended sediment on fish, Newcombe and Jensen (1996) developed an empirical model which estimates the Severity of Ill Effects (SEV) Index. The SEV Index represents the biological impacts to salmonids and other fish species, resulting from exposure to various suspended sediment concentrations and durations. This empirical model utilizes fisheries and suspended sediment research which correlate concentrations to an observed effect on the sampled population, such as salmonid avoidance of turbid waters, reduced feeding rates, reduced growth rates, or death. Newcombe and Jensen provides a useful means of evaluating if exposure to the measured suspended sediment concentrations and durations have an adverse effect on salmonid beneficial uses in the Elk River watershed. Table 3.4 presents the range of severity of ill-effects, as indexed by the authors, which fish experience upon exposure to excess suspended sediment.

Table 3.4 Severity of Ill Effects Index describing effects associated with excess suspended sediment.[44]

SEV	Description of Effect
	Nill Effect
0	No behavioral effects
	Behavioral Effects
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
	Sublethal Effects
4	Short-term reduction in feeding rates; Short-term reduction in feeding success
5	Minor physiological stress; Increase in rate of coughing; Increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation
8	Indications of major physiological stress; Long-term reduction in feeding rate; Long-term reduction in feeding success; Poor condition
	Lethal and Paralethal Effects
9	Reduced growth rate; Delayed hatching; Reduced fish density
10	0-20% mortality; Increased predation; Moderate to severe habitat degradation
11	>20-40% mortality
12	>40-60% mortality
13	>60-80% mortality
14	>80-100% mortality

A SEV value of 4, corresponding to short term-reduction in feeding rates and success could be considered as an important threshold over which conditions are not fully supportive of beneficial uses. While the SEV values are expected to vary throughout the year, the longer the time period that the SEV value exceeds 4, the greater the estimated impact on the conditions of juvenile salmonids and their subsequent ability to survive ocean conditions.

Since sediment transport responds to runoff, the suspended sediment and turbidity water quality monitoring data should be viewed in the context of rainfall. Table 3.5 provides the annual rainfall volumes, as measured by NOAA at the Woodley Island Station in Eureka, as well as the relative percentage of average rainfall, for the hydrologic years analyzed in this section. Figures 3.26-3.30 present the resulting predictions of percent time in which

[44] Table 1 of Newcombe and Jensen (1996).

different severity index values are exceeded at Upper Elk River monitoring stations during hydrologic years 2003-2007.

Table 3.5 Annual rainfall volume and relative percentage of average annual rainfall volume in Eureka (38.83 inches) (Woodley Island - NOAA National Weather Service).

Hydrologic Year	Rainfall Volume (inches)	Percentage of Average Annual Rainfall
2003	54.18	140%
2004	38.75	100%
2005	43.46	112%
2006	58.68	151%
2007	35.35	91%

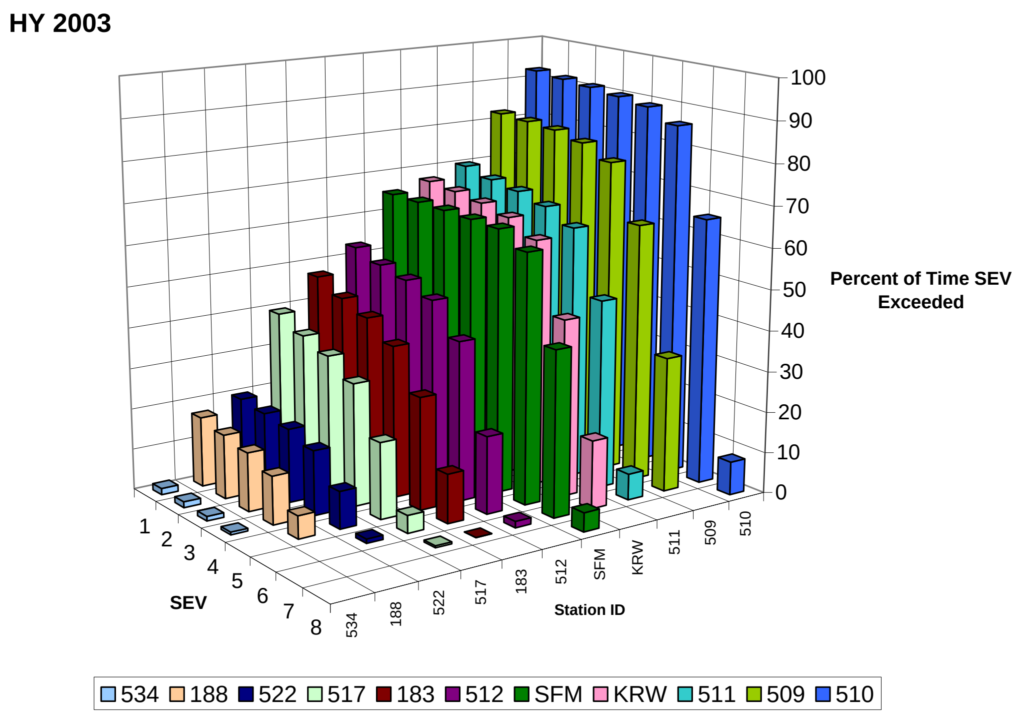


Figure 3.26 Percent of time SEV values exceed at Upper Elk River stations for HY 2003

Precipitation was 140% of normal in HY 2003. The 2003 data are spread largely based on drainage area (i.e., the larger drainage areas show the greatest percentage of time at higher SEV levels). Station 510 on the lower South Fork Elk River shows the greatest SEV values, indicating the potential for major physiological stress, long-term reduction in feeding rate and success, and poor condition (SEV 8). With the exception of Stations 534 on Little South Fork Elk River, Station 188 on upper South Fork Elk River, and Station 522 on Corrigan Creek, all stations demonstrate conditions predicted to have short term impacts on salmonid feeding rates and success (SEV 4) at least 20% of the time.

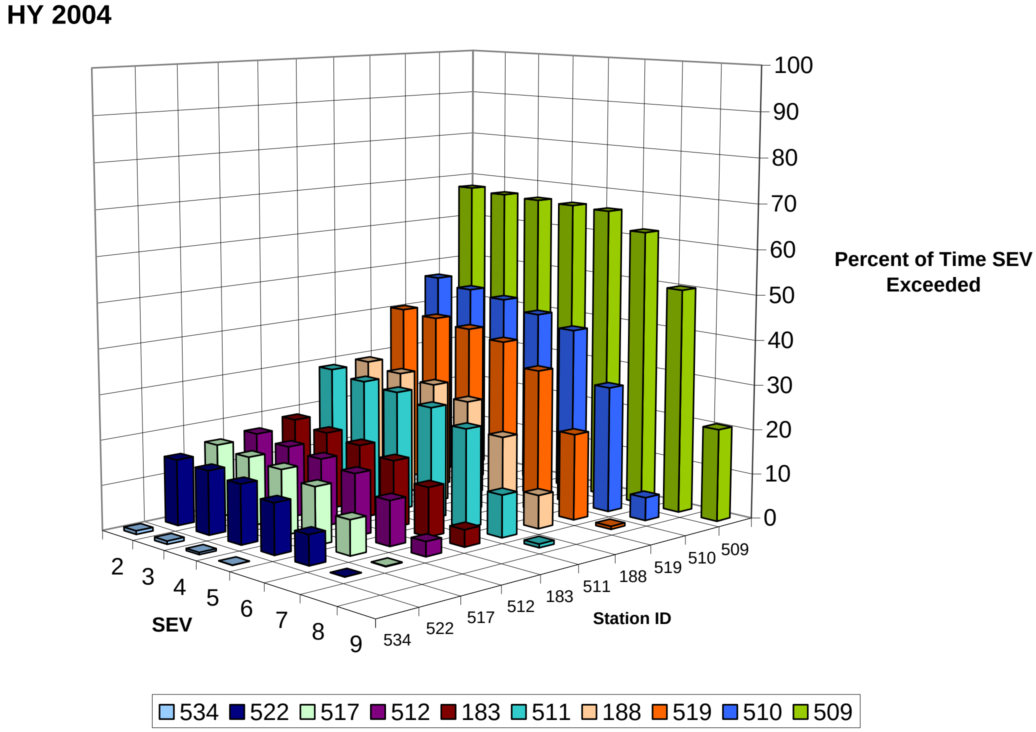


Figure 3.27 Percent of time SEV values exceed at Upper Elk River stations for HY 2004.

HY 2004 was an average rain year. Conditions at Station 509 (upper Mainstem Elk River) are predicted to have the greatest potential impact to juvenile salmonids. Reduced growth rate, delayed hatching, and reduced fish density (SEV 9) are predicted to occur nearly 20% of the time, while indications of major physiological stress, long-term reduction in feeding rate and success, and poor condition (SEV 8) were estimated nearly 50% of the time. Station 510 (lower South Fork) and Station 519 (South Branch North Fork Elk), demonstrate conditions in which moderate habitat degradation (SEV 7) is predicted to occur around 20% of the time, and moderate physiologic stress (SEV 6) is predicted to occur around 30% of the time. Data for Station 188 (upper South Fork Elk River) and Station 511 (lower North Fork Elk River) demonstrate conditions predicted to result in minor physiologic stress, increased rates of coughing and respiration (SEV 5) approximately 20% of the time.

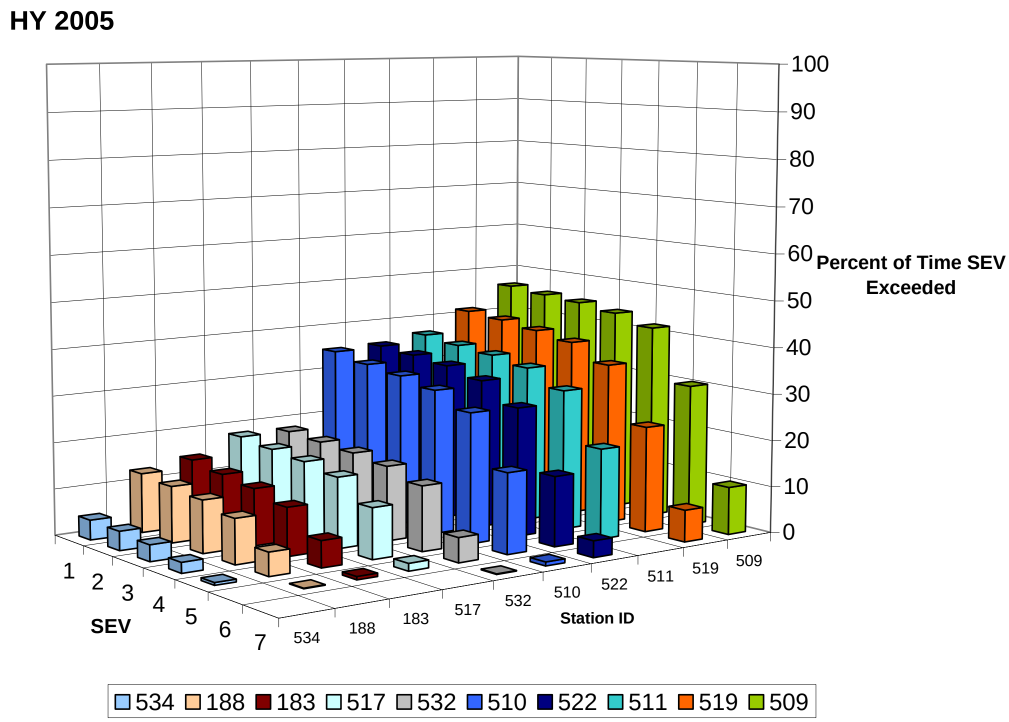


Figure 3.28 Percent of time SEV values exceed at Upper Elk River stations for HY 2005.

The rainfall in HY 2005 was 112% of average rainfall (HY 2004). The data from Station 509 demonstrated that conditions at this site had the potential for the greatest impacts to salmonids, although the estimate is less than that developed for HY 2004. Short-term reduction in feeding rates and success were estimated to occur 20% to 30% of the time at Stations 532, 510, 522, 511, 519, and 509. Data collected at Station 522 (Corrigan Creek) indicate an unusually high suspended sediment load in this year, compared to earlier years and especially when considering the small drainage area.

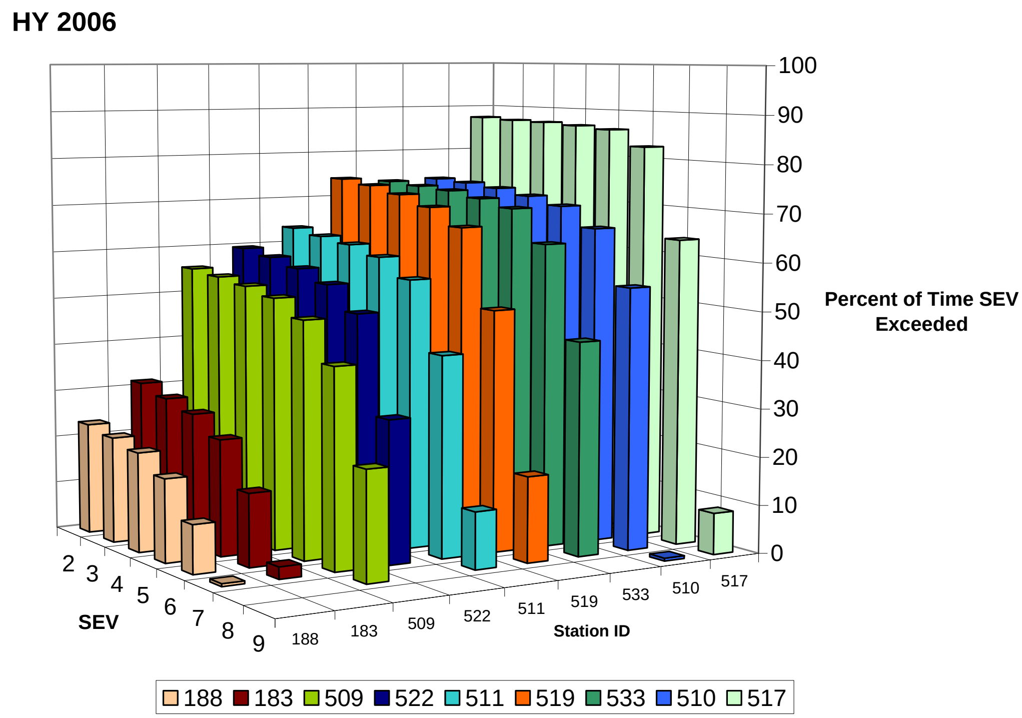


Figure 3.29 Percent of time SEV values exceed at Upper Elk River stations for HY 2006

The HY 2006 precipitation was 151% of average. In HY 2006, Station 517 (Bridge Creek) demonstrated conditions with the greatest predicted impacts to salmonids due to suspended sediment concentrations. This was an unexpected finding given the relatively small drainage area (2.2 mi^2) of the subbasin. In Bridge Creek, the lethal and paralethal effect for reduced growth rate, delayed hatching, and reduced fish density (SEV 9) were estimated just less than 10% of the time, and sublethal effects including moderate habitat degradation (SEV 7) were estimated 80% of the time. Station 509, 522, 511, 519, 533, and 510 all demonstrated chronically high suspended sediment concentrations much of the time, with short term reduction in feed and feeding success rates (SEV 4) estimated approximately 50-60% of the time, while Stations 183 and 188, were predicted to have a SEV 4 approximately 20% of the time.

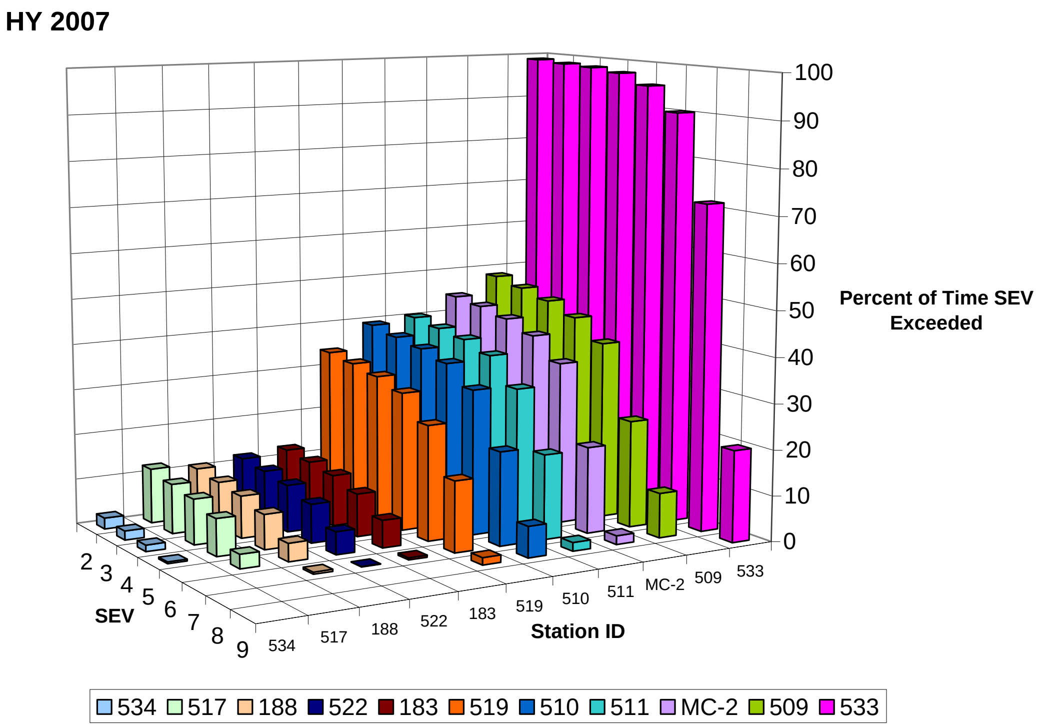


Figure 3.30 Percent of time SEV values exceed at Elk River stations for HY 2007.

HY 2007 had 91% of average annual rainfall. Station 533 (Tom's Gulch), with a drainage area of 2.5 mi^2, demonstrated the most extreme conditions predicted for salmonids of the HY year. Estimated lethal and paralethal effects of reduced growth rate, delayed hatching and reduced fish mortality (SEV 9) were predicted nearly 20% of the time and indications of major physiological stress, long term reduction in feeding rate and success, and poor condition (SEV 8) were predicted 70% of the time. Stations 519, 510, 511, MC-2, and 509 are somewhat grouped with moderate physiological stress (SEV 6) occurring approximately 20% of the time and short term reduction in feeding rates and success (SEV 4) estimated to occur between 30% to 45% of the time. Station MC-2 (McCloud Creek), drainage area of 2.3 mi^2 was added in HY2007. It should be noted that in HY 2007, Stations 510 and 511 (lower South Fork and lower North Fork, respectively) are more similar than in the other years analyzed. Stations 517, 188, 522, and 183 were predicted to experience short term reduction in feeding rates and success (SEV 4) less than 10% of the time.

While the SEV Index analyses are but one measure of potential impacts to the cold water fisheries of Upper Elk River, they indicate that throughout the basin salmonids are predicted to be experiencing sublethal effects much of the time, and in some locations, lethal and paralethal effects for a shorter cumulative period of the time. This data confirms that sediment concentration and duration are problematic for salmonids in Upper Elk River.

Turbidity

Turbidity data was used to compare managed subbasins with a reference subbasin, (the study subbasins described in Appendix 4-C). Data generated during an average rainfall year[45] formed the basis of the analysis between the reference subbasin (Little South Fork Elk River) and two managed subbasins in Upper Elk River (Corrigan Creek and South Branch North Fork Elk River). The discharges, measured in cubic feet per second (cfs), were normalized by drainage area (mi^2). Rating curves were constructed for turbidity (measured in nephelometric turbidly units (NTU)) versus discharge per unit area measured in cubic feet per second (cfs/mi^2). Linear trend lines were fit to the data for each station. The resulting trend lines are plotted in Figure 3.25. The data presented in the figure indicates the extent to which turbidity levels vary for the same discharge per unit area.

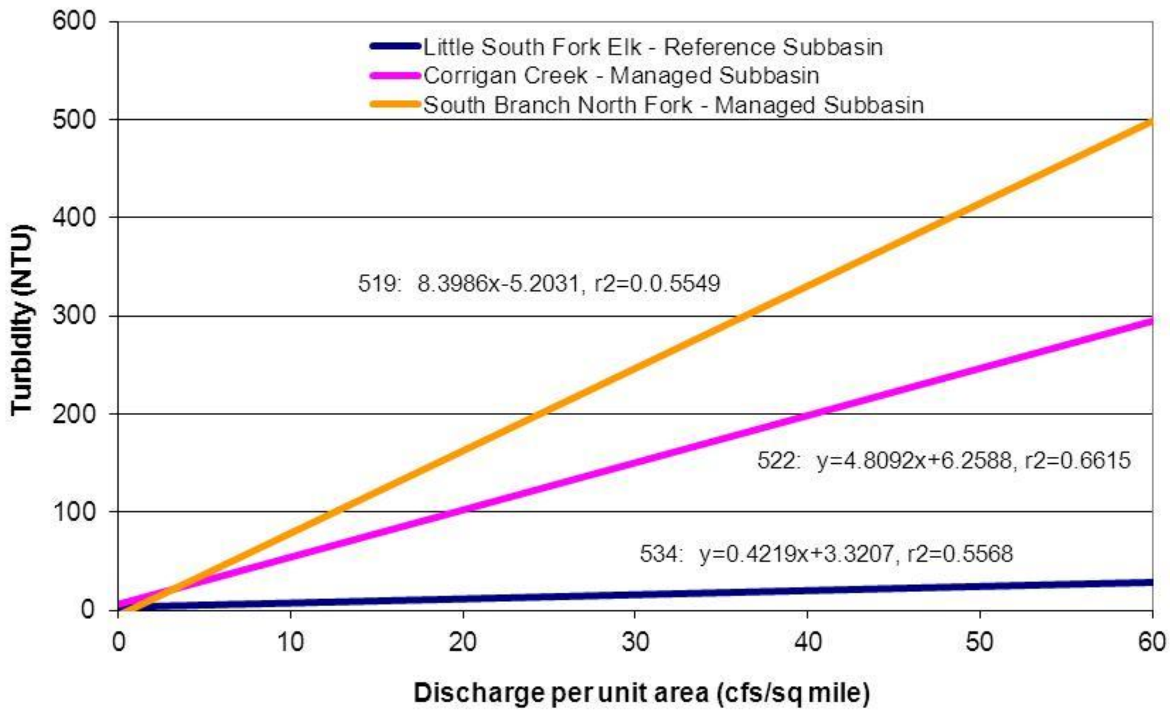


Figure 3.31 Comparison of ratings curves for three subbasins in Elk River.

The data indicate that Corrigan Creek turbidity levels are 281% to 930% greater than reference levels and the South Branch North Fork Elk River turbidity levels are 178% to 1,642% greater than reference levels, at low to high discharges, respectively.

Although there is uncertainty associated with regression analysis comparing subbasins and variability in natural conditions, this analysis demonstrates that there is significant

[45] HY 2004 was selected for use as an average rainfall year in the Upper Elk TMDL analysis.

discrepancy between natural and managed basins in Elk River with respect to turbidity. These turbidity differences (far greater than 20%) provide ample evidence that the water quality objective for turbidity is exceeded over a range of discharges and turbidity levels and are attributable to land management activities.

3.5 Conclusion

There is ample evidence to substantiate the significant impairment to the beneficial uses of water in the Upper Elk River watershed, including the loss of agricultural and domestic water supplies, the development of conditions that result in elevated rates of flooding, the loss or damage to spawning habitat and rearing habitat, and water quality conditions which cause feeding and health difficulties for salmonids. Recent and ongoing high sediment loads, in combination with the Upper Elk River's instream hydraulics and the chemical and physical properties of the sediment load result in the excessive deposition of fine sediment, elevating the channel base and constricted channel width. Armoring of the channel is ongoing by both sediment particles and vegetation, further locking in an elevated base elevation. Channel cross-sectional areas continue to be reduced due to sediment deposits. Data also indicate the significant role management activities play in the impairment of sediment-related water quality conditions in the Upper Elk River watershed with adverse effect on beneficial uses and the development of nuisance.

CHAPTER 4. Sediment Source Analysis for the Upper Elk TMDL

Key Points

- The source analysis quantifies the timing and magnitude of past sediment loading associated with both natural and management-related hillslope sediment sources. Natural sources are estimated as a long-term average. Management-related sources were estimated for several analyses time periods defined by aerial photograph pairs.
- The source analysis is data rich and is informed by sediment data collection and mapping efforts by a wide spread of professionals associated with agencies, timber companies, private consultants, and research institutions.
- Site-specific sediment inventory data were provided by Upper Elk landowners and evaluated at a sub-basin scale. If site-specific data were unavailable, loadings were developed based upon field-surveys in three study sub-basins located in in Upper Elk River.
- A channel initiation study informed estimates of the natural and management-related drainage densities over time. The current drainage network has incised headward as a result of management activities and the drainage density is estimated to have increased three-fold.
- A variety of analytical approaches are used to estimate natural and management-related sediment loads, including literature values, field surveys in study subbasins in Upper Elk River and nearby Freshwater Creek including a reference area of Headwaters Forest Reserve, aerial photographs, GIS mapping, landuse history, erosion monitoring conducted in Elk River, and application of erosion models.
- Natural sediment sources identified and quantified include streambank erosion, streamside landslides, shallow hillslope slides and deep-seated landslides. The long-term average loading from natural sources (1955-2011) is estimated to be 68 $yd^3/mi^2/yr$.
- Management-related sediment sources identified and quantified include low order channel incision, stream bank erosion, road-related shallow hillslope landslides, open-slope shallow hillslope landslides, streamside landslides, management-related sediment discharge sites, post-treatment discharge sites, skid trail features, road surface erosion, and harvest (in unit) surface erosion. The largest management-related sediment loading is associated with streamside landslides, open-slope shallow landslides, road-related landslides, and road surface erosion.
- Management-related loading was estimated for several analysis time periods including 1955-1966, 1967-1975, 1975-1987, 1988-1997, 1998-2000, 2001-2003, and 2004-2011. The long-term average management-related loading is estimated to be 976 $yd^3/mi^2/yr$ (approximately 1000% of natural loading). The largest management-related loading is associated with the 1988-1997 time period.

4.1 Introduction to the Upper Elk River Sediment Source Analysis

This chapter presents the sediment source analysis developed for the Upper Elk TMDL (Source Analysis). The purpose of a TMDL sediment source analysis is to describe the sources of sediment discharge that are impacting the beneficial uses of water in an impaired waterbody. The Source Analysis includes sources associated with both natural and management-related processes that affect sediment delivery in the Upper Elk River. The analysis also provides a quantification of the magnitude and timing of sediment source delivery to Upper Elk River.

4.2 Overview of Sediment Source Analysis Development

The Source Analysis relies largely upon the data contained in the numerous existing sediment source inventories which landowners in the Upper Elk River watershed began to develop in 1997. The data collection efforts were developed in part in response to Regional Water Board CAOs and WDRs conditions, and in part for ownership-specific management purposes. See Appendices 4F and 4G for more information regarding these inventories.

The sediment source inventories present data relative to both discrete sources as well as providing estimated erosion rates for the various physical processes at work in the watershed. Sediment source data developed for the adjacent Freshwater Creek watershed, which has similar physical characteristics and land management history as the Elk River watershed, were also used to inform the Source Analysis.

In addition, new data sets were developed for categories in which Regional Water Board staff identified a significant level of uncertainty associated with available data. Where site specific data were unavailable, generalized rates were developed and applied. A summary of the sources of uncertainty identified by Regional Water Board staff, including the use of generalized rates are included, as appropriate.

The following data sets were used in the development of the Source Analysis:

1) Sediment source inventory summary for Pacific Lumber Company lands in North Fork Elk River (Pacific Watershed Associates (PWA), 1998).
2) Sediment source inventory summary for Pacific Lumber Company lands in South Fork and Upper Mainstem Elk River (PWA, 2001).
3) Shallow landslide data and attribute information for discrete landslide features identified on aerial photos on and near Pacific Lumber Company lands in North Fork, South Fork and Upper Mainstem Elk River (Palco, 2004b).
4) Site specific data and attribute information of road-related sediment discharge sites on Pacific Lumber Company lands in North, South and Mainstem Elk River (Palco, 2004c)
5) The Pacific Lumber Company Elk River Salmon Creek Watershed Analysis sediment budget (Palco, 2004).
6) Cleanup and Abatement Orders sediment source database which incorporated and built upon earlier source inventory efforts (Humboldt Redwood Company (HRC), 2010).

7) Pacific Lumber Company Report of Waste Discharge Landslide database submission of aerial photo data, road data and 2003 landslides data integrated into one database (Palco, 2005c).[46]
8) Inventory of skid trail related sediment sources in Freshwater Creek (Palco, 2007).
9) Inventory of road-related sediment discharge sites on Green Diamond Resource Company lands in South Fork Elk River (PWA, 2006).
10) Inventory of non-road sediment discharge sites on Green Diamond Resource Company (GDRC) lands (GDRC, 2007, 2008, 2009, & 2010).
11) Inventory of the road system and a portion of the skid trail-related sediment discharge sites within the Headwaters Forest Reserve (PWA, 2000, 2004, & 2005).
12) Aerial photograph interpretation of shallow landslides within the old-growth portion of the Headwaters Forest Reserve (PWA, 2008).
13) Bank erosion surveys of portions of Elk River and Freshwater Creek (PWA, 2006).
14) Aerial photograph interpretation and field surveys for small streamside landslides in portions of Elk River and Freshwater Creek (PWA, 2008).
15) Staff field surveys to establish the headward extent of low-order stream channels.
16) Evaluation of various studies estimating sediment discharge volumes generated as a result of sediment control treatments (Palco (2006& 2007), GDRC (2005&2006), PWA (2005a & b), Klein (2003), Madej (2001), Bloom (1998), and BLM (2010).
17) Evaluation of timber harvest history data in Elk River (CDF (2010), Palco (2005b)).
18) Shallow landslide data and attribute information for discrete landslide features identified on aerial photos on and near Humboldt Redwood Company lands in Upper Elk River (HRC, 2012a)
19) Sediment Budget as developed for Watershed Analysis on Humboldt Redwood Company Lands in Elk River (HRC, 2012b)

The time periods evaluated in this Source Analysis reflect past sediment delivery. Some sediment sources persist and are not necessarily a reflection of sediment loading resulting from current management measures. The analysis time periods correspond to aerial photograph periods used in the identification of sediment sources, primarily landslide sources. The analysis time periods considered in this sediment source analysis include 1955-1966, 1976-1974, 1975-1987, 1988-1997, 1998-2000, and 2001-2003.

Additionally, the sediment loads associated with different source categories for the time period between the years 2001 to-2011 were analyzed by Humboldt Redwood Company

[46] Subject to a data use agreement (Palco, 2005) GIS information was provided to Regional Water Board contractors but not to Regional Water Board staff. Contractors provided the Regional Water Board with data analyses, summaries, and model outputs. Due to data use restrictions, some data analyses were limited associated with this sediment source analysis.

(HRC) associated with the revisit of the *Watershed Analysis for the Elk River* (HRC 2012) required as part of their approved Habitat Conservation Plan (HCP).

The approaches used to characterize aspects of the Source Analysis, included use of:

- A subbasin study to compare reference and management conditions of specific erosional processes;
- An empirical sediment budget to assess sediment production of specific land classes; and
- A study characterizing the effects of management on low order channel initiation and its effects on drainage density.

These approaches are summarized below and described in more detail in Appendices 4A through 4C.

Study Subbasin Approach

In order to characterize specific erosion related parameters, discharge rates, and sediment loads in Upper Elk River, three of the subbasins located in the Upper Elk River were selected for detailed study. The results of the subbasin studies were used to develop generalized sediment loading rates (delivery per unit area) which were extrapolated, as appropriate, to apply to Upper Elk River. The three study subbasins have similar physical characteristics with differing land management histories. Two of the subbasins, South Branch North Fork Elk River and Corrigan Creek have been subject to logging activities while the third subbasin, Upper Little South Fork Elk River is a nearly pristine old-growth subbasin. The location of the three study subbasins are shown in Figure 4.1.

Data from the three study subbasins were used to compare the following erosional processes and their relative natural and management-related sediment loads:

- Drainage area associated with initiation of headward incision of low-order stream channels (see Appendix 4C).
- Sediment delivery rates of streamside landslides (see Appendix 4E).
- Sediment delivery rates of stream bank erosion (see Appendix 4D).
- Landslide feature size detection limits for aerial photograph analysis.

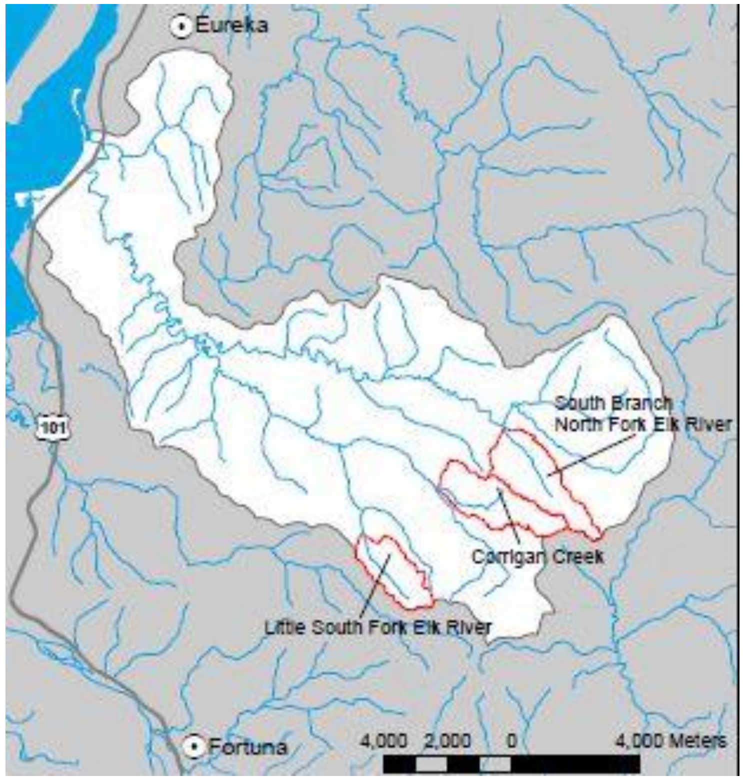


Figure 4.1 Location of study subbasins within Upper Elk River (Buffleben (2009)).

Empirical Sediment Budget Approach

The Empirical Sediment Budget Approach stratifies a watershed into distinct land classes as a basis for quantifying sediment production using empirical coefficient rates. Similar to the study subbasin approach in which otherwise similar managed versus unmanaged areas are compared for relative rates of sediment delivery, the empirical sediment budget approach groups similar areas, differing by their management level, and compares the sediment production per unit area. The two approaches differ, however, in that the empirical sediment budget approach defines the sediment production rates for the land classes rather than the use of generalized rates developed from a small, representative area for extrapolation to larger areas. By grouping similar areas in the basin into discrete land classes, data analyses may be conducted at a scale that provides meaningful results due to a greater sample size.

Modeling watershed sediment production in this manner allows for the subdivision of the landscape into logical land class categories based on physical processes governing erosion and other pertinent factors, such as management-related land disturbance. Consequently, the model can be tailored to differences that exist within watersheds. Likewise, the model may be used to describe a comprehensive sediment budget or can be tailored to evaluate individual source components of a sediment budget.

Channel Initiation Study

Quantification of sediment delivery to the stream channel network includes not only inventory of discrete erosion features and determination of erosion rates, but also a quantification of the extent of the stream channel network. The stream channel network can be modeled through identification of the headward extent of channels and characterization of the associated drainage area necessary for the formation of those channels. The resulting drainage density can be calculated as length of stream channel per area of watershed (mi/mi^2). Sediment source inventories can be conducted along a known length of channel resulting in sediment delivery estimates per channel length and then applied to a greater areal extent based upon the drainage density therein.

Timber harvesting and the construction of skid trails used to transport timber to the road system leads to increases in peak flow, ground water interception, soil compaction and drainage diversion. All of these factors contribute to upslope (headward) incision of stream channels reducing from natural conditions the drainage area necessary to initiate stream channels, and increasing the density of the stream channel network (Buffleben, 2009).

As part of the Elk River TMDL analysis, and within the in the three study sub-basins described in Appendix 4A, Regional Water Board staff conducted surveys designed to 1) develop appropriate drainage area thresholds for channel initiation; 2) determine how the drainage area associated with channel formation varied with management activity; and 3) determine the associated drainage density for use in the Upper Elk River sediment source analysis. Details of the channel initiation surveys, analyses, and results are included as Appendix 4C. The resulting drainage densities estimated for different geologic formations, by decade, are presented in Table 4.1. Source category evaluations that utilized these drainage densities include soil creep, bank erosion, and streamside landslides.

Table 4.1. Drainage density associated with Upper Elk River geologic formations, by decade.

Time period	1950 (Natural)	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009 (Current)
Percent of current drainage density present by decade		75%	80%	85%	90%	95%	100%
Wildcat and Yager Drainage Density (mi/mi2)	5.6	12.4	13.2	14.0	14.8	15.6	16.5
Franciscan Drainage Density (mi/mi2)	5.6	8.8	9.4	10.0	10.6	11.2	11.7
Hookton Drainage Density (mi/mi2)	5.6	12.4	13.2	14.0	14.8	15.6	16.5

4.3 Natural Sediment Sources

As part of this Source Analysis, sediment sources associated with natural conditions were evaluated and quantified. The natural source categories identified in the Source Analysis include soil creep, streambank erosion, streamside landslides, hillslope landslides, and deep-seated landslides.

A description of each of the identified natural sources is presented below. A summary of the analysis methods used, data results, and identification of uncertainties associated with each source category are included for each source category.

Natural Soil Creep

As used in this Source Analysis, soil creep is defined as a natural process in which soil and/or rock debris slowly moves downslope under the influence of gravity. Colluvium (rock and other related debris derived from the hillslope) is supplied to stream banks via soil creep at a rate equal to the stream bank erosion rate, if equilibrium conditions are assumed. Reid and Dunn (2003) describe soil creep as difficult to monitor accurately with few measurements available.

Staff evaluated the use of two methods for estimating the relative magnitude of soil creep as a natural source category. The two techniques include:

1) Application of a soil creep rate as developed at similar sites, multiplying the estimated creep rate per unit width by the length of the streambank. This method is anticipated to yield estimates of low accuracy.
2) Estimate sediment production from bank erosion and streambank landslides instead. The resulting estimates are expected to be of medium accuracy.

Buffleben (2009) reviewed a suite of measured soil creep rates developed in temperate rainforests of northern California and their applicability to Upper Elk River. He found that of the available estimates, that made by Lehre (1987) was most applicable (0.37 $cm^3/cm/yr$). That estimate corresponds to a rate of 0.078 $yd^3/mi/yr$ and based upon a natural drainage density estimate of 5.6 mi/mi^2, the sediment loading from soil creep would be 0.44 $yd^3/mi^2/yr$.

As part of the development of the TMDL, bank erosion and streambank landslides surveys in the Upper Elk River were conducted. Based on the availability of this watershed specific data set, staff determined that the use of this data would provide a more accurate estimate than using soil creep rates developed in other areas. The following sections cover the methods and resulting loading estimates associated with natural bank erosion and streambank landslides.

Natural Stream Bank Erosion

For the purposes of this study, bank erosion is defined as stream bank erosion caused by lateral migration of streamflows (i.e. flow deflection or stream undercutting). Bank erosion does not include streamside hillslope failures (mass wasting), or stream channel incision (vertical down cutting) caused by fluvial processes.

Pacific Watershed Associates (PWA, 2008) was commissioned by the Regional Water Board to assess stream bank erosion rates within the Upper Little South Fork Elk River reference study subbasin using a stream bank erosion void assessment method (Reid and Dunne 1996; PWA 1999; PALCO 2007). This source analysis relies upon their inventories as a basis for both natural and management-related bank erosion sediment loading. The report, *Elk River Bank Erosion Void Assessment and Bank Erosion-Related Wood Inventory* is included as Appendix 4D.

Bank erosion volumes for erosion features greater than five cubic yards (>5 yd^3) of delivery were inventoried under this approach. These volumes were estimated by measuring bank erosion height and root exposure depth along lengths of eroded stream bank. The volume of bank erosion was computed as:

Bank erosion height (ft) x root exposure depth (ft) x length of eroded channel (ft)

Bank erosion sites less than five cubic yards (<5 yd^3) were tallied by stream order and erosion from these sites was estimated by multiplying the number of smaller features by an average delivery of 2.61 yd^3 (2 m^3) per site.

Unit bank erosion (yd^3/mi) was determined for 1st, 2nd, 3rd and greater than 4th order channels[47] based on the total estimate of field inventoried bank erosion (>5 yd^3 and <5 yd^3 features combined) in each stream order. Unit sediment delivery was then extrapolated to the total length of stream (by stream order) in each of the study subbasins.

Specific bank erosion void attributes were collected on field data forms for erosion features with sediment delivery >5 yds^3 and mapped on 1:1200 LiDAR based DEM shaded relief field maps. The specific bank erosion attributes collected in the field are presented below. The locations of bank erosion sites <5 yds^3 were flagged in the field and mapped on the field maps. Data forms were not filled out for the smaller features.

Seventeen randomly selected stream reaches were inventoried in the Little South Fork Elk River reference study subbasin. Inventoried stream reaches within this subbasin averaged approximately 176 meters in length. The stream reach inventory included approximately 900 meters of 1st order streams; 590 meters of 2nd order streams, 750 meters of 3rd order streams, and 760 meters of 4th order and greater streams. The dominant substrate observed during the inventory was primarily sand sized particles with minor amounts of cobble and gravel. The channel morphology of the sampled 1st and 2nd order streams were formed primarily by subsurface flow. The channel morphology observed in the 3rd, 4th order and higher order stream reaches were predominantly low gradient riffles. The 4th order and higher stream reaches were all located in the mainstem portion of the Little South Fork Elk River.

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47 The stream layer developed for Upper Little South Fork Elk River assumed a 0.8 hectare drainage area as the area need to initiate channel formation. This stream layer was used to classify stream order (PWA, 2008).

The unit bank erosion sediment delivery rate calculated for Little South Fork Elk River was 0.045 m^3/m (94.72 yd^3/mi) for the 57 year period between 1950-2007. Assuming a natural stream drainage density of 5.6 mi/mi^2, the annual natural stream bank erosion rate was calculated to be 9.36 $yd^3/mi^2/yr$.

Uncertainty is associated with the estimates established through the analysis due to the following considerations:

- The bank erosion inventory estimates assumed a uniform erosion rate throughout the 1950-2007 time period. However, because delivery rates vary with streamflow, the application of a uniform rate over the study time period overestimates the inputs rates during dry periods and underestimates them during periods of higher flows.
- Natural bank erosion likely varies spatially with differences in geology, hillslope, and stream gradients affecting erosion rates. The bank erosion analysis assumes a uniform rate across the Elk River watershed.

Natural Small Streamside Landslides

As used in this Source Analysis, small streamside landsides are considered to be those landslide features that originate from streamside slopes and are too small to detect on aerial photographs. To develop the rate of natural streamside landsliding, data from the Little South Fork Elk River reference subbasin was used.

Recent studies evaluating the effects of land management on landslide initiation rates have indicated that the presence of landslides may be masked during aerial photography analysis in forest lands dominated by a relatively closed forest canopy. This can result in a bias in estimating landslide rates in harvested areas versus areas of old-growth or relatively closed canopy. PWA (2006) describes the ranking factors affecting landslide visibility on aerial photographs, indicating that canopy conditions, as a surrogate for land use, is the most important factor influencing landslide visibility.

PWA (2006) conducted an aerial photo and field-based comparison of three distinct forest canopy types: 1) old-growth, 2) advanced second-growth and 3) recently (less than 15 years ago) clearcut areas in the Elk River and Freshwater Creek watersheds. This study provided estimates of the relative streamside landslide erosion and delivery associated with each of the three canopy types. This study was also designed to estimate relative levels of uncertainty associated with using aerial photo interpretation for landslide detection. Applicable pages excerpted from the PWA Report, *Freshwater Creek TMDL Sediment Source Assessment, Phase I,* dated August 2006, is included as Appendix 4E.

In 2006, PWA (2006) surveyed 3.6 miles of channel in the Upper Little South Fork Elk River subbasin for evidence of past or recent streamside landslides. Only landslides that delivered to the stream system were included in the inventory. Each feature was inventoried based on volume (greater than or less than ten cubic yards). Average dimensions and sediment delivery estimates were also recorded for each feature.

Landslides were age-dated using geomorphic and vegetative site conditions (scarp morphology, slide scar re-vegetation, leaning trees, sapling growth whorls, soil bareness, type of cover (herbaceous versus trees), etc.) and placed in one of three age categories: 1) 1975–1987; 2) 1988–1997; and 3) 1998–2003). This age determination required professional judgment. Landslides that initiated during these time periods would be subject to potential identification on air photos from 1987, 1997 and 2003. Landslides judged to pre-date 1975 and post-date 2003 were mapped but not inventoried on data forms.

Within the 3.6 miles of stream sampled for this streamside landslide analysis, 12 small (<10yd^3) landslide features were identified for a total sediment delivery of 60 yd^3, with an average sediment delivery of 5 yd^3 per site. A total of 8 large (>10 yd^3) landslides were identified for a total sediment delivery of 352 yd^3 and an average delivery volume of 44 yd^3 per feature. All of the 8 large landslides were field identified as debris slides, 2 were associated with Wildcat Group and 6 were located within terrain dominated by the Yager Formation. Four large slides were attributed to the 1975 through 1987 time period, 2 were attributed to the 1988 through 1997 period, and 2 were attributed to the 1998 to 2003 period. The conifer overstory canopy ranged from 40% to 95% and the understory cover ranged from 60% to 95% across the study area. None of these features were detected on aerial photographs. The PWA inventory did not attribute time period to the smaller features. For the purposes of this analysis, Regional Water Board staff assumed the small landslides occurred during the same time frames proportional to those of the large landslides.

Table 4.2 presents the unit channel delivery from small and large streamside landslide inputs. The PWA surveys indicate total combined inputs from natural small and large streamside landslides was 1.9, 1.6, and 5.3 yd^3/mi^2/yr, for the photo periods 1975-1987, 1988-1997, and 1998-2003, respectively. The 29-year average based upon the PWA surveys is 3.95 yd^3/mi/yr.

While the PWA surveys were based upon a drainage network with an assumed 0.8 hectare drainage area for channel formation, the Channel Initiation Study (described in Appendix 4C) indicates that the channels in the unmanaged area were initiated with a 4.2 hectare drainage area. In managed areas, channel initiation was associated with a 0.5 hectare drainage area. Consequently, in the Upper Little South Fork Elk River, PWA conducted surveys of swales located upslope of areas with a smaller drainage area than in their previous survey. Evaluation of these results indicated that approximately 1.05 miles of additional stream length was included in the adjusted survey. This led to the identification of 6 additional features (5 small and 1 large), for a total estimated volume of 69 yd^3. Adjustment of the data by staff to exclude these survey lengths and features results in an adjustment of the annual average sediment delivery from natural stream side landslides from 3.95 yd^3/mi/yr to 4.63 yd^3/mi/yr.

Because it is unknown to Regional Water Board staff which time period was assigned to the excluded features, the adjusted long-term average loading was applied to the subbasins in this Source Analysis. Table 4.2 presents the results of the adjusted PWA surveys. As presented in this table, the annual average loading from natural streamside landslides is 26.08 $yd^3/mi^2/yr$ (based upon a delivery of 4.63 $yd^3/mi/yr$ and a natural drainage density of 5.63 mi/mi^2).

Figure 4.2 shows the PWA results, as well as the long-term average based upon the adjusted results.

Table 4.2 Results of streamside landslide surveys based upon adjusted PWA surveys (all photo periods combined)[48]

Small streamside landslide feature	Number of features	Average volume (yd^3)	Total Volume (yd^3)	Volume per channel length (yd^3/mi)	Annual average volume per channel length ($yd^3/mi/yr$)
Small (<10 yd^3)	7	5	35	13.70	0.47
Large (>10 yd^3)	7	44	308	120.58	4.16
Small and Large Combined	14	--	343	134.29	4.63

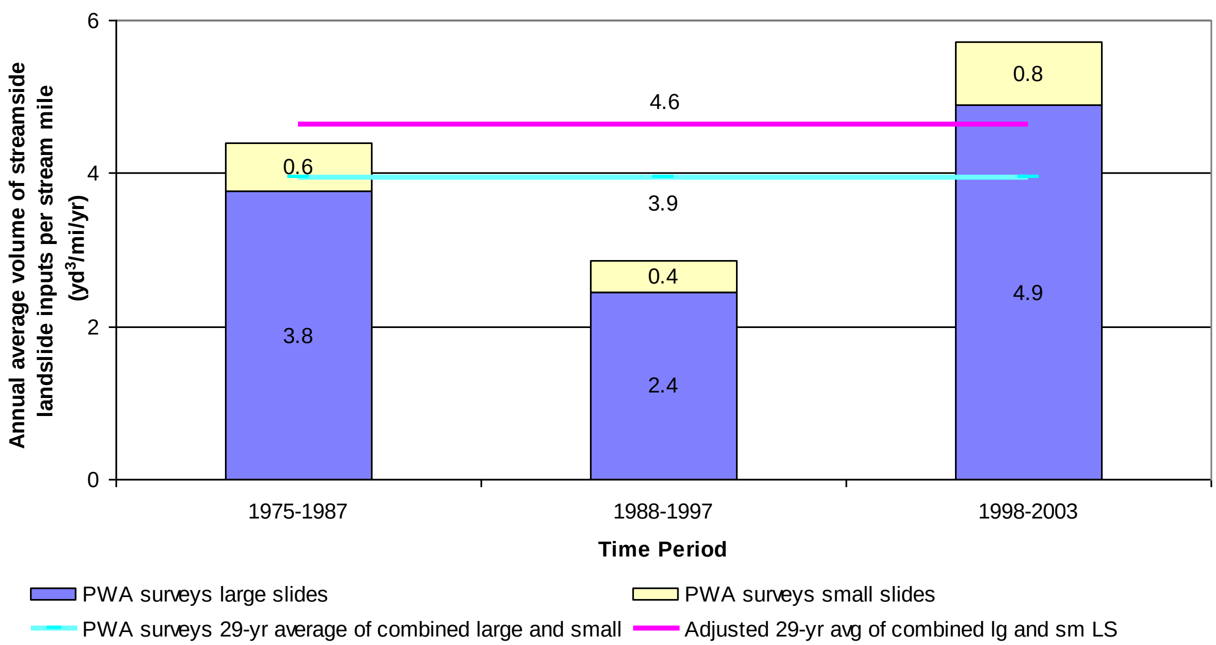

Figure 4.2 Annual average delivery per channel length from streamside landslides in reference study subbasin. The original PWA surveys are represented by bars. The lines indicate the 29-year average based upon the original and the adjusted PWA surveys.

[48] Adjusted to exclude stream lengths and features upslope of the drainage network used in this source analysis (based upon a 4.2 ha drainage threshold).

Uncertainty associated with the estimates for natural streamside landsliding established through the Source Analysis includes:

- The PWA surveys were adjusted to exclude channel segments and features surveyed and identified by PWA that were actually upslope of the natural drainage network as identified in Appendix 4C. This adjustment may have introduced error by 1) the excluded channel lengths being either over or under estimated; 2) the excluded features may have had volumes significantly different than the average volumes for large or small features.
- The dating of streamside landslide features and the placement of the features into the appropriate photo period was subject to best professional interpretation by the field crews. Thus, the actual time period for sediment delivery from any specific feature may be different than that used in the calculations. Uncertainty associated with time period increases with older features. The long-term average was used in this sediment source analysis.
- The natural drainage density likely varies depending on topography and geology. However, a fixed value of 5.6 mi/mi^2 was used for all areas regardless of hillslope gradients. The areas where this assumption is expected to least accurately reflect actual drainage densities is in flood-prone areas, thus leading to an over estimate of natural sediment loadings from these areas.

Natural Shallow Hillslope Landslides

As used in this Source Analysis, shallow hillslope landslides are landslide features that are typically visible on aerial photographs with a size of greater than 400 ft^2 with sediment delivery to streams. Considerations important in the characterization of naturally occurring shallow hillslope landslides include:

- Minimal management influence on hillslope landslide rates.
- Acknowledgement of spatial and temporal variability of landsliding.
- Data quality comparable to that associated with management-related landslide data.
- Determination of the level of management influence is verifiable and objective.

Two approaches were evaluated to determine reasonable estimates of natural hillslope landslide sediment delivery volumes for use in the Source Analyses. One method is based upon data derived from the Upper Little South Fork Elk River reference study subbasin (Reference Watershed Approach). The other, the Empirical Sediment Budget approach, is based upon developing estimates using data from those areas in the watershed that have not been subject to recent harvesting activity (i.e. no harvest in the last 15 years). These approaches are based on information presented in Appendices 4A and 4B of this report. The results from each approach are presented below.

As part of the development of the Reference Watershed Approach, Regional Water Board staff identified the Upper Little South Fork Elk River as the subbasin that most closely represented natural or unmodified sediment delivery rates and hydrologic process at work in the Elk River watershed. Data from this subbasin were then used to characterize natural (background) conditions for Upper Elk River. The Upper Little South Fork Elk River is also referred to as a reference watershed.

The Reference Watershed Approach assumes a natural hillslope landslide loading based upon the loading derived from aerial photo analyses conducted within the old-growth portions of Upper Little South Fork Elk River subbasin (PWA, 2008).

An aerial photo analysis of the Upper Little South Fork Elk River using four sets of historic aerial photos (1987, 1997, 2003, and 2007) [49] was conducted to identify landslides with sediment delivery potential within the 1.20 mi^2 subbasin (PWA 2006). To compile the landslide history for the Upper Little South Fork Elk River, each new landslide which appeared on the photographs was added to the inventory. Specifically, all visible recent or active landslides with a minimum area of 400 ft^2 that deliver sediment to streams were mapped and feature attributes were recorded.

[49] Air photos used in this Source Analysis were obtained from Pacific Lumber Company and analyzed using a stereoscope in their Scotia office.

Landslide depths were determined by using a linear regression equation developed for the *Freshwater Creek Sediment Source Investigation* (PWA, 1999). The following equation is based on the relationship between landslide surface area using field data collected during the field verification phase of this 1999 investigation, where:

$$Depth=0.00024*Area + 1.426\ (R^2 = 0.52)$$

Landslide volumes were calculated from the areas derived from the aerial photos and depths derived from the regression curve. A maximum of 15 ft. depth was assumed for landslides greater than 57,000 ft^2. The features identified using the Reference Watershed Approach were not field verified. PWA estimated percent delivery for the features based upon aerial photo interpretation.

In the Upper Little South Fork Elk River, PWA (2008) identified 2 landslides during the 1988-1997 photo period for an estimated delivery of 107 yd^3, 1 landslide during the 1998-2003 photo period for an estimated delivery of 382 yd^3, and 2 landslides during the 2004-2007 photo period for an estimated delivery of 510 yd^3. Figure 4.3 shows the average annual sediment loading associated with natural landslides based on the Reference Watershed Approach. The average sediment loading for 1988-2007 (weighted by length of photo period), based on the Reference Watershed Approach, is 41.6 $yd^3/mi^2/yr$.

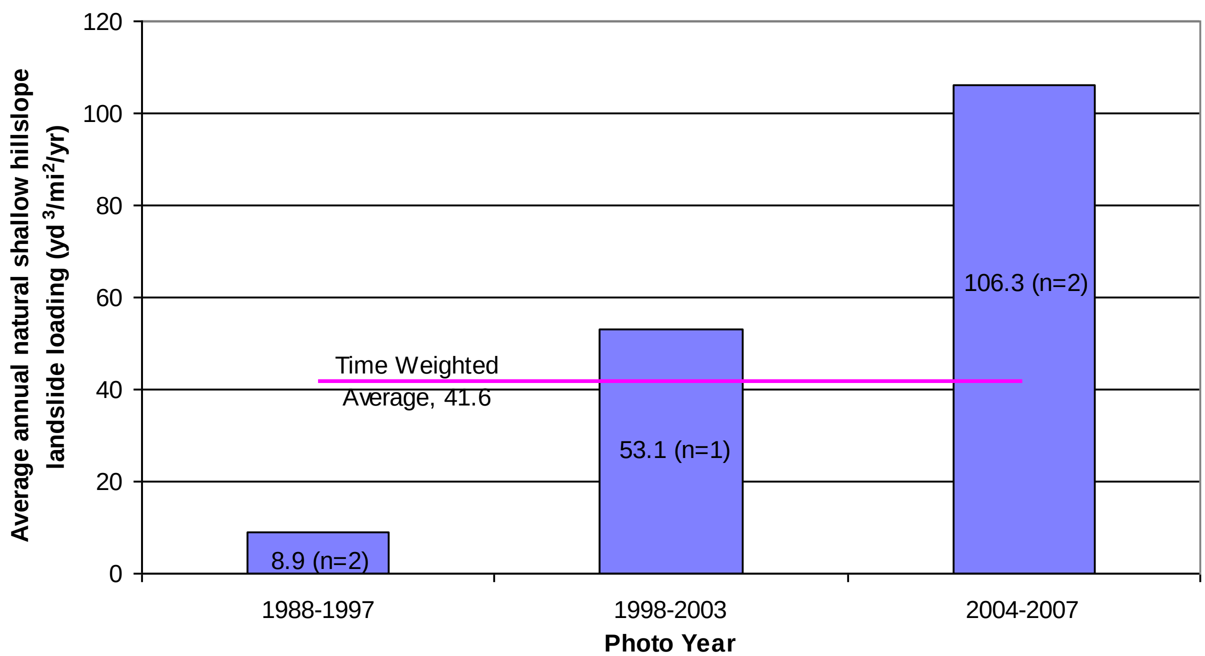

Figure 4.3 Natural shallow hillslope landslide sediment loading ($yd^3/mi^2/yr$) based upon the reference study subbasin for available photo periods, as determined by Reference Watershed Approach.

The limited number of landslide features (sample size) inventoried for use in the Reference Watershed Approach has the potential to significantly influence the loading within a given photo period. The relatively small size of the little South Fork Elk River may be insufficient to characterize natural hillslope landslide loading throughout the watershed. Additionally, PWA (2008) assigned a measure of certainty to the identified features which ranged from medium to low.

As another line of evidence, staff also used the Empirical Sediment Budget approach to develop a second estimate of sediment delivery volumes from natural shallow hillslope landslides. This approach evaluated areas that had not been harvested in the fifteen years prior to initiation of a landslide event. The Empirical Sediment Budget approach relied on data developed for defined geologic groupings, rather than using data at the individual subbasin scale. Staff utilized this approach as the results produced at the finer subbasin resolution resulted in spatial areas too small to provide good measures of representative rates (i.e. too small of a sample size).

The Palco landslide database (Palco, 2005)[50] contained an inventory of 1,144 landslides. The Empirical Sediment Budget approach was applied to this data set and was used to develop a volume estimate of sediment delivered from shallow hillslope landslides within areas not subject to timber harvesting within the past fifteen years.

The Palco landslide database was used to identify landslides within the subbasins. Those data were then combined into geologic group (Table 4.1), sorted by the aerial photo year that the landslide was first visible, and by landslide attributes [e.g., indications that the landslide occurred within 15 years of harvest or long after (> 15 years) after harvest activity (as per the land classes in Table 4.2). The landslide delivery volume associated with areas not recently harvested was summed by photo period, for each of the geologic groups. The total volume per “un-harvested” land class was then determined for each of the photo periods for which there was corresponding harvest history data (1988-1997, 1998-2000, 2001-2003).

Table 4.3 presents the natural land-class groupings based upon geology. Table 4.4 presents the portion of the geologic groups that were not subject to harvest in the 15 year period prior to landslide initiation.

[50] Final Report of Waste Discharge (Palco, 2005). The excel spreadsheet database contains entries, including past delivery volumes, for 1144 landslides.

Table 4.3. Geologic groups, subbasins, grouping criteria, and associated drainage areas of seventeen Upper Elk River subbasins for use with the Empricial Sediment Budget Approach.

Group	Subbasin	Geologic Grouping Criteria	Area (mi^2)
A	Bridge Creek Dunlap Gulch Browns Gulch McWhinney Creek Lake Creek McCloud Creek	100% Wildcat	9.50
B	Lower North Fork Elk River Lower South Fork Elk River Tom Gulch	>75% Wildcat, remainder Hookton	10.42
C	South Branch North Fork Elk River Little South Fork Elk River Corrigan Creek	>75% Wildcat, remainder Yager	7.18
D	Railroad Gulch Clapp Gulch	>50% Hookton	2.20
E	Upper North Fork Elk River North Branch North Fork Elk River	Presence of Franciscan	8.38
F	Upper South Fork Elk River	Yager dominated	6.45

Table 4.4 Land class areas (*ai*) (dimensionless)

Landslide period	1988-1997	1998-2000	2001-2003
Period of no harvesting	**1973-1997**	**1983-2000**	**1986-2003**
Geologic Group	***Percent of area not harvested in last 15 years,*** (a_i)		
A	75%	73%	68%
B	85%	83%	82%
C	75%	75%	83%
D	70%	70%	70%
E	69%	66%	65%
F	42%	42%	41%

The data presented in Table 4.4 was derived using the Empirical Sediment Budget approach and depicts the reference land class areas (by Geologic Group) as a portion (percentage) of each of the areas that had not been harvested in the past 15 years. The smallest percent of areas not harvested in the past 15 years for all photo periods is included in Geologic Group F at 41%. .

Table 4.5 depicts the sediment production from the land class areas which have not been harvested in the past fifteen years (reference production). The area-weighted and time-weighted averages are also presented.

Table 4.5 Reference Sediment Production Coefficient (r_i)

Landslide period	**1988-1997**	**1998-2000**	**2001-2003**	**Time weighted average**
Period of no harvesting	**1973-1997**	**1983-2000**	**1986-2003**	
Geologic Group	***Annual volume of sediment delivered per unit area from areas not harvested in last 15 years (yd³/mi²/year)***			
A	36	0	2	23
B	107	7	42	76
C	1	40	0	8
D	153	25	0	100
E	0	0	11	2
F	6	0	0	4
Area weighted average	**42**	**9**	**12**	**30**

Figure 4.4 depicts the different sediment loading estimates for shallow hillslope landslides as determined by the Reference Watershed Approach and the Empirical Sediment Budget Approach.

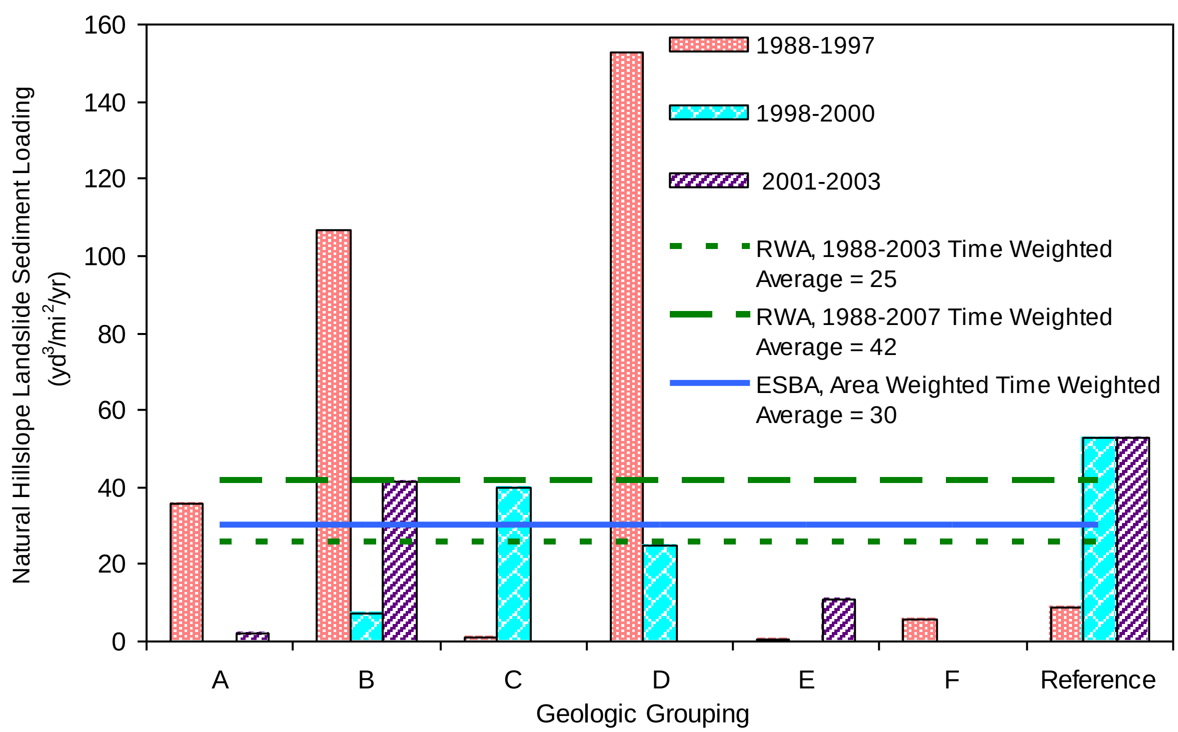

Figure 4.4 Natural shallow hillslope landslide sediment loading estimates based upon the Reference Watershed Approach and the Empirical Sediment Budget approach.

Staff determined that the area weighted time weighted average derived from the Empirical Sediment Budget Approach (1988-2003, 30.1 yd³/mi²/yr) provides the most reasonable estimate sediment load derived from natural shallow hillslope landslide loading.

Because the number of landslides available for evaluation in the Reference Watershed Approach was too small to provide meaningful results, Regional Water Board staff chose the used of the Empirical Sediment Budget approach as mostly likely to yield a conservative and reasonable estimate of sediment loading from this natural source category.

Data derived from recently harvested areas likely over-estimate natural landslide rates since:

1. It is unlikely that root strength recovers to natural conditions in 15 years.
2. Hydrologic changes associated with rainfall interception and evapotranspiration resulting from harvesting is unlikely to return to old-growth conditions in a 15 year period.
3. The harvest history is not well documented prior to 1986. Thus, uncertainty in harvest history prior to landslides in the 1988-1997 photo period may result in either under or overestimation of rates.

Natural Deep-Seated Hillslope Landslides

As part of the report, *Landslide Hazard in the Elk River Basin,* Stillwater (2007) reports:

> "Large storm events can activate debris slides and rotational landslides associated with pre-existing deep-seated landslide features (De La Fuente, et al. 2002). Despite the potential importance of deep-seated landslides to sediment delivery, the physical factors controlling deep-seated mass movement are poorly understood and few physical models have been developed to assess deep-seated landslide hazards (Miller 1995). Deep-seated landslide morphology is typically characterized by crescent-shaped major and minor scarps; flat-lying and backtilted blocks; benched topography; and lobate accumulation zones with hummocky topography, seepage lines and springs, ponded and deflected or irregular drainage patterns. Deep-seated landslides and their corresponding level of activity are typically identified based on interpretation of these topographic signatures on maps and aerial photographs. Confirmation of these features is supplemented by field observations. These approaches, however, require substantial effort, are limited by vegetation that obscures relevant features, and require professional judgment based on experience with the local geology and topography. This approach can result in the production of a hazard map that is based on subjectivity and would be difficult to replicate."

A suite of tools for objective delineation of terrain prone to deep-seated landslides and earthflows using high-resolution digital topographic data is currently being developed (McKean and Roering 2004, Roering et al. 2005, Mackey et al. 2005, Mackey et al. 2006, Roering et al. 2006). These deep-seated landslide and earthflow detection (DSLED) algorithms identify terrain that has already experienced deep-seated slope instability, and thus has a higher potential for reactivation (Roering et al. 2006). The methods provide predictive power in identifying slide-prone terrain, and are best utilized as reconnaissance tools in combination with aerial photographic interpretation and field mapping. The models are being developed and tested at sites in the northern California Coast Range, Western Cascade Range of Oregon, and elsewhere (Roering et al. 2006). The models have been used to successfully identify deep-seated mass movement associated with the Franciscan melange in the nearby Eel River basin (Mackey et al. 2005, Mackey et al. 2006). Two of the three DSLED algorithms, DSLED Rough and DSLED Drain, were used to identify surface roughness and drainage patterns associated with potential deep-seated mass movement in the Elk River basin. As work is accomplished to characterize the type, boundaries, timing, and activity level of deep-seated landslides in the basin, efforts should be made to better validate the deep-seated model results and develop appropriate hazard classes.

Two deep-seated landslide inventories were conducted in the Elk River watershed. Hart Crowser produced one as part of the *Elk River/Salmon Creek Watershed Analysis* (Palco, 2004) and the California Geologic Survey (CGS) produced the other as part of their mapping of *Geologic and Geomorphic Features Related To Landsliding in Elk River* (Marshall & Mendes, 2005). The Palco (2004) Watershed Analysis inventory included landslide activity level[51] that allowed an estimate of sediment delivery rates to be developed. The CGS map does not identify this activity level or any information from which to determine sediment delivery rates. As such this sediment source analysis relied on the Palco (2004) inventory for estimates of the deep seated landslide delivery as the best available information.

A deep seated landslide inventory as developed for and presented in the *Upper Elk River Watershed Analysis* (Palco, 2004) includes 336 deep-seated features were identified within the Elk River watershed assessment area. The larger features average 30 acres in size, with the surface features averaging 22 acres in size. Of the inventoried features, 90.5% were classified as dormant, 6.8% were classified as relict. Palco (2004) considered the delivery of sediment from dormant historic, dormant, and relict deep-landslide features to be part the background soil creep estimates. Two features demonstrated activity within the available photo record. Palco (2004) assumed a rate of movement for these active features at 1 foot per year. This estimate was based upon the low end of reported rates for earthflow movement in the local area (Kelsey 1978), because there is no local data on the rate of movement of active deep-seated landslides other than for earthflows. The active features were identified in Upper South Fork Elk and Tom's Gulch and had cross-sectional areas at the toes of 3,000 ft^2 and 400 ft^2, respectively. Palco (2004) attributed these deep seated features to natural sources.

Only the two identified "active" deep-seated features, as included in the *Palco Watershed Analysis* (WA), were included explicitly in this Source Analysis as natural sources. The sediment delivery associated with these features, based on their size and a rate of one-foot per year, results in natural deep-seated delivery of 17.2 $yd^3/mi^2/yr$ in Upper South Fork Elk River and 5.9 $yd^3/mi^2/yr$ in Toms Gulch. It was assumed that the delivery of sediment from features classified as anything but "active" would be included in the loading estimates for the other source categories.

[51] Based after Keaton and DeGraff (1996).

Uncertainty is associated with the estimates established through the analysis due to the following considerations:

- Recent activity has been observed at the toes of features in the Lower South Fork TMDL subbasin that are mapped as "dormant" features (Pers. comm. Sam Flannigan, 2011). Staff assumed that the landslides at the toes of deep-seated landslides are captured in the shallow hillslope landslide inventory and thus are accounted for in this sediment source analysis.
- Staff assumed that sediment delivery from the active deep-seated features is natural. Movement of deep-seated features may be aggravated by management activities including hydrologic changes and road cuts. These effects are not incorporated into this analysis.
- More work is needed to characterize the type, boundaries, timing, and activity level of deep-seated landslides in the basin in order to better validate the deep-seated model results and develop appropriate hazard classes.

Summary of Natural Sediment Loading

The natural sediment source analysis is based largely upon rates determined from within the watershed. Figures 4.5 and 4.6 present the annual average loading from the various source categories in $yd^{3/}/mi^2/yr$ and $tons/mi^2/yr$, respectively. As used in this Source Analyses, the annual average sediment loading, with the exception of deep seated landslides[52], is uniform throughout the basin.

The sediment source analysis indicates that the largest inputs associated with natural sediment sources in the Elk River basin are shallow hillslope landslides and stream bank landslides.

[52] Active deep seated landslides have been identified in two subbasins, Toms Gulch and Upper South Fork Elk River, with annual average loading of 5.9 and 17.2 $yd^3/mi^2/yr$, resulting in a total natural loading of 66.1 and 77.4 $yd^3/mi^2/yr$, respectively

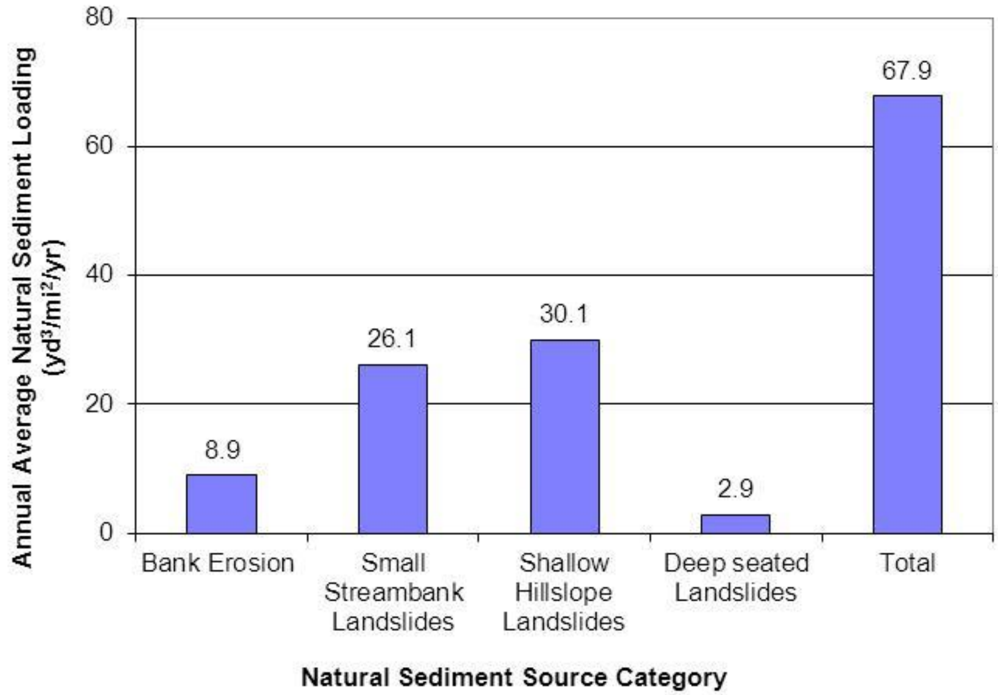

Figure 4.5 Summary of annual average loading from natural sediment sources in the Elk River watershed ($yd^3/mi^2/yr$).

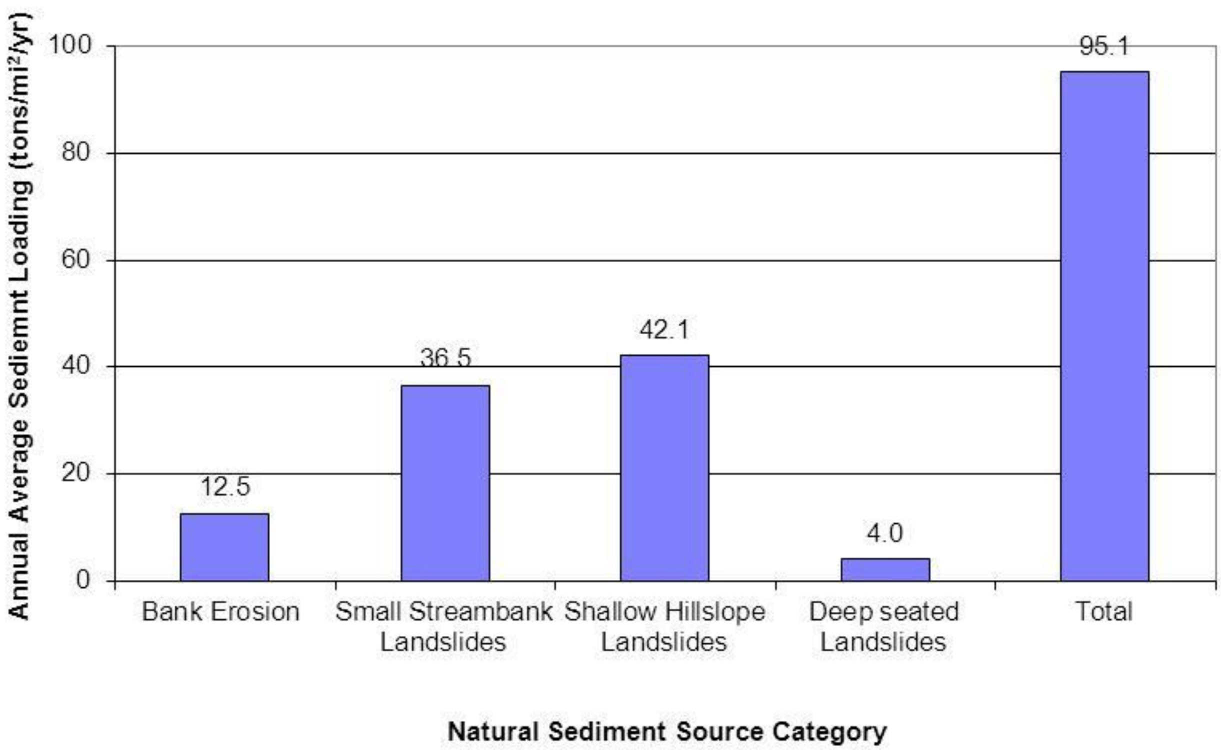

Figure 4.6 Summary of annual average loading from natural sediment sources in the Elk River watershed ($tons/mi^2/yr$).

4.4 Management-Related Sediment Loading (1955 to 2003)

Management activities, such as rates of timber harvesting, harvest method, yarding method, road construction and reconstruction and restoration (cleanup of controllable sediment sites) can all affect the creation of sediment sources and discharge rates associated with those sites. The sediment sources affected by management activities in Upper Elk River include:

- Low order channel incision (headward scour).
- Stream bank erosion
- Road-related shallow hillslope landslides
- Open-slope shallow hillslope landslides
- Small streamside landslides.
- Management-related sediment discharge sites (e.g. gullies and stream crossing erosion features)
- Post-treatment discharge sites (e.g. erosion following correction of controllable sediment delivery sites).
- Skid trail features (e.g. diverted watercourses, compacted soil).
- Road surface erosion.
- Harvest (in unit) surface erosion.

The controllable water quality factors which affect management-related sediment source categories are presented in Table 4.6.

Table 4.6 Management-related sediment source categories and the controllable water quality factors that have affected them in Upper Elk River.

Management-Related Sediment Source Category(s)	Controllable Water Quality Factors
Channel Incision in Low Order Streams	· Tractor and vehicle crossings in swales · Alteration of trees within swale · Hydrologic modification in upslope drainage area · Soil compaction in upslope drainage area
Stream Bank Erosion and Streamside Landslides	· Tractor and vehicle crossings in swales · Rate and scale of land disturbance in upslope drainage area · Hydrologic modification in upslope drainage area · Alteration in sediment loading in upslope drainage area · Alterations in riparian condition, composition, and area · Alterations in slope stability · Alteration in channel stability
Road Related Landslides	· Overall road density · Density of low and mid-slope roads · Inadequate site evaluation · Inadequate road design · Inadequate road construction standards · Alterations in slope stability · Hydrologic connectivity, drainage structure sizing and protection · Alteration in riparian vegetation and area
Open Slope shallow landslides	· Alterations in slope stability · Rate and scale of land disturbance · Alterations in riparian condition, composition, and area
Management Discharge Sites, Skid Trails, and their Treatment	· Creation of new sites · Inventory and prioritization of existing sites · Treatment of existing sites · Method of site treatment · Site characterization · Equipment used for treatment · Timing of treatment · Channel, slope and headwall stabilization · Remediation response time and materials
Deep Seated Landslides	· Identification of features · Drainage on features · Alteration of trees on features
Road Surface Erosion	· Surface material treatments · Overall road density · Density of low and mid-slope roads · Road shape · Winter-period use
Harvest Surface Erosion	· Ground disturbance and compaction · Rate and scale of land disturbance · Hydrologic modification · Disturbance on slopes greater than 20% · Tree removal

The discussion on management-related sources present in this Source Analysis has been subdivided into two subsections to reflect the availability of new information since the analysis of sediment sources first began. Section 4.3 presents data for the time period 1955 to 2003, while Section 4.4 presents data for the 2004 to 2011 time period.

Each of the sediment source categories identified in Table 4.6 is described below, including 1) identification of the analysis methods used; 2) summary of the data results; 3)uncertainties associated with each source category; and 4) implications for watershed implementation actions.

Management-Related Channel Incision

Scour of low-order channels (headward migration of the stream channel) can occur as a result of management-related activities. To provide data relative to this source category Regional Water Board staff developed a Channel Initiation Study to collect watershed specific data. See Appendix 4C for more information regarding the study. The data from this study provided evidence that drainage density increased from the headward incision of watercourses following timber harvest activities. The increase in channel density affects both the volume of sediment discharged per unit area as well as increasing the length of stream channel that is susceptible to direct sediment inputs. This Source Analysis accounts for this volume of sediment as management induced low-order channel scour.

Drainage density (DD) between subbasins was evaluated to determine the difference in channel length for each of the subbasins. This was determined as:

$$(DD_{Managed}*Area_{subbasin})-(DD_{Natural}*Area_{subbasin})=Length_{Channel\ Scour}$$

Regional Water Board staff assumed that the management-related headward migration of channels occurred in low-order (1st and 2nd order) channels. The average channel dimensions were determined based upon data collected by staff from both the Regional Water Board and PWA in the study subbasins. Specifically, average channel depth was estimated using data collected as part of the Regional Water Board surveys. This evaluation indicated channel depth ranged from 0.5 to 2.0m (average=1.25 m, 4.1 ft) (Buffleben, 2009). Average channel width was based upon the 1st and 2nd order channels surveyed in the three study subbasins by PWA (2008) which ranged from 0.28 to 1.6 m (average=0.8m, 2.64 ft). These same dimensions were applied to the Franciscan and Hookton formations.

Thus the total volume of channel scour was calculated as:

$$Length_{Channel\ Scour}\ x\ Depth_{\ Low\ order\ channel}\ x\ Width_{\ Low\ order\ channel}$$

Regional Water Board staff assumed that the first 75% of the current sediment loading resulting from channel initiation was attributable to the first cycle logging which staff assumed occurred in the 1950's. Staff attributed the remaining sediment load from this source to the subsequent decades at a rate 5% of the current total per decade, averaged evenly over each year. Staff assumed that 100% of the eroded sediment volume was delivered to the fluvial system.

Based upon the estimated changes in drainage densities over time for each of the geologic formations Regional Water Board staff calculated the annual average sediment loading by analysis period since 1950. The results are presented in Table 4.7.

Table 4.7 Sediment loading ($yd^3/mi^2/yr$) associated with management-related headward initiation of low order channels by time period.

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Wildcat, Yager, Hookton Low Order Channel Initiation Loading ($yd^3/mi^2/yr$)	74	25	14	23	34	13
Franciscan Low Order Channel Initiation Loading ($yd^3/mi^2/yr$)	37	18	10	16	24	9
Upper Elk River Low Order Channel Initiation Loading ($yd^3/mi^2/yr$)	67	23	14	21	32	12

Uncertainty is associated with these estimates due to the following considerations:

- Staff assumed a uniform time period for channel initiation due to lack of a comprehensive harvest history to support a more refined estimate.
- These estimates do not account for channel storage or routing rates but are rather estimates of sediment loads discharged to the stream network.
- The estimates assume the total channel cross-section eroded as a result of headward incision. In some cases, there was likely a soil pipe void that expanded so as to initiate headward incision. Not considering that void results in an over estimate of the scoured volume.

Control of sediment loading from channel initiation in low order channels may be accomplished by:

1) Avoiding new tractor crossings in unchanneled swales and in areas where the upslope drainage area is greater than that required for channel initiation
2) Limiting peak flow increases in swales where the drainage area is greater than that required for channel initiation.
3) Promoting trees for stability within swales and areas of subsurface flow paths to minimize soil pipe collapse.

Management-Related Stream Bank Erosion

For the purposes of this Source Analysis, management-related stream bank erosion is defined as the acceleration of stream bank erosion (lateral migration of streamflows) due to human activities. As with the natural bank erosion source category, this source does not include streamside hillslope failures (mass wasting), or stream channel incision (vertical down cutting) caused by fluvial processes.

Pacific Watershed Associates (PWA, 2008) conducted a comparison of stream bank erosion rates in the three study subbasins; Corrigan Creek, South Branch North Fork Elk River and Little South Fork Elk River. The subbasins were selected to represent managed (Corrigan Creek, and South Branch North Fork Elk River) versus unmanaged areas (Little South Fork Elk River). This comparison study, Study Subbasin approach, is described in more detailed in Appendix 4A. The rates developed from this study were used to determine bank erosion-related inputs for the various subbasins. Regional Water Board staff multiplied the PWA-determined rates by subbasin stream length, both for natural and current drainage networks, to determine the bank erosion inputs. The difference between the current inputs and the natural inputs is attributed to management.

The results from the Little South Fork Elk River surveys are discussed in Section 4.2. Corrigan Creek and South Branch North Fork Elk River exhibited nearly the same unit stream bank erosion sediment delivery for the entire stream network within these managed subbasins (0.143 m^3/m and 0.144 m^3/m, respectively). For this Source Analysis, Regional Water Board staff relied on a value of 0.14 m^3/m, or 303 yd^3 per mile of stream channel over the 57 year time period to estimate the total bank erosion rate. The natural stream bank erosion rate in the Little South Fork Elk River, as calculated from field survey data is 0.05m^3/m or 94.72 yd^3 per mile of stream for the 57 year time period.

Using the estimated natural and management-related drainage densities, as presented in Section 4.2, the stream lengths were determined based on the subbasin areas. The management-related bank erosion loading was calculated as the managed stream bank erosion rate minus the natural stream bank erosion rate, times the drainage density:

$$\textit{Management-related bank erosion loading} = (BE_m - BE_n) x DD_m$$

The sediment loading associated with stream bank erosion was calculated for each geologic formation based upon the drainage network estimated for each of the analysis time periods since the 1950s. The management-related stream bank erosion loading was calculated as that for the managed streams adjusted to eliminate the natural inputs. The resulting loadings from management-related bank erosion are presented in Table 4.8.

Table 4.8 Management-related sediment loading associated with stream bank erosion.

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Wildcat, Yager, Hookton Management-related Bank Erosion Loading ($yd^3/mi^2/yr$)	46.67	49.79	52.76	56.31	57.90	58.50
Franciscan Management-related Bank Erosion Loading ($yd^3/mi^2/yr$)	33.29	35.52	37.63	40.17	41.31	41.73
Upper Elk River Management-related Bank Erosion Loading ($yd^3/mi^2/yr$)	44.13	47.08	49.89	53.24	54.75	55.32

Uncertainty associated with the management-related bank erosion estimates include:

- Estimates of drainage densities over time. Staff assumed a uniform time period for channel initiation due to the lack of a comprehensive harvest history to support a more refined estimation.
- The estimates do not account for channel storage or routing through the system.
- Rates are applicable to the Upper Elk River watershed. Harvest history, including silvicultural and yarding techniques, and the level of riparian protections influence bank erosion loading.

Management related stream bank erosion may be controlled to some level by:

- Avoiding additional management related headward channel incision.
- Promoting stable channels in equilibrium by reducing sediment loading and enhancing structural stability.
- Limiting hydromodification from timber harvesting and road influences to prevent additional scour

Management-Related Shallow Hillslope Landslides

In this Sediment Source Analysis, management-related shallow-hillslope landslides include road-related landslides and open slope landslides. Consistent with the evaluation for natural sources, shallow hillslope landslides are defined as landslide features which are typically visible on aerial photographs with a size of greater than 400 ft^2. This source category is intended to include those shallow hillslope landslides that were initiated by management-related actions. Due to complex hillslope processes that influence landsliding and the inherent difficulty in assigning a causal mechanism to a landslide, especially for earlier time periods, determination of a slide feature as either natural or management related is difficult. Rather than assigning a cause (management-related or natural) to each individual slide, the management-related landslide delivery is defined as the total landslide delivery minus the 30.1 $yd^3/mi^2/yr$ natural rate of shallow hillslope landsliding (as described in Section 4.3) and is described in the following equation:

$$Landslide_{Management} = Landslide_{Subbasin} - Landslide_{Natural}$$

As such, the Source Analysis categorizes those slides that exceed the natural value as being management-related. This section presents information relative to all landslide categories, their attributes, and provides an estimate of the sediment loading from management-related landslides. Data is organized to present landslide data by ownership, with road and non-road related slides segregated from open-slope shallow landslides. Much of the area has undergone ownership and management style changes over the analyses time periods; as such the management-related shallow landslide analysis may not accurately reflect current management strategies.

Two landslide data sets were evaluated by Regional Water Board staff for use in determining sediment loading from shallow hillslope landslides in the Upper Elk River watershed. Information from these two data sets, with modifications described below, was used to develop an estimate of management-related shallow hillslope landslide loading.

1. Palco Watershed Analysis Landslide Database (WA Database)[53]. The aerial photo review for the *Elk River Watershed Analysis* (Palco, 2004b) was the basis for a landslide database that covers the dominant ownerships in the seventeen TMDL subbasins covered by this Source Analysis. The data set contains attributes and past delivery estimates for 856 landslides. Unfortunately, spatial information for these landslide features could not be determined directly from the map that was submitted.
2. Palco ROWD Landslide Database (ROWD Database)[54]. This dataset, presented in an excel spreadsheet, contains 1,144 landslide features, including 820 features identified in the PWA aerial inventory (PWA, 2004b), 260 landslides from the PWA road dataset (PWA, 2004c), and 64 identified during a 2003 inventory conducted by Palco Geology Department. Under a 2005 data use agreement with Palco (Palco 2005), spatial data associated with the features was not provided to the Regional Water Board staff for evaluation[55]; rather, staff worked with a map in pdf format.

To determine sediment loading from shallow hillslope landslides on the individual dominant ownerships, Regional Water Board staff used the following approach:

- For BLM lands, staff relied upon the WA Database. Staff identified slides on BLM lands from this data source by visually consulting the associated map and property lines.
- For GDRC lands, staff relied upon the WA Database. Landslides were also identified in the WA Database as part of the GDRC ROWD (GDRC, 2006).

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53 Palco (2004b). Shallow landslide data and attribute information for discrete landslide features identified on aerial photos on and near Palco lands in North Fork, South Fork and Upper Mainstem Elk River.

54 Palco Report of Waste Discharge Landslide (Palco, 2005).

55 Subject to a data use agreement (Palco, 2005) in which the GIS information may be furnished to Regional Water Board contractors but not to Regional Water Board staff; rather, contractors may provide the Regional Water Board with data analyses, summaries, and model outputs. Due to data use restrictions, some data analyses were limited associated with this sediment source analysis.

- For HRC lands, staff relied upon the ROWD Database (with landslides data for features on GDRC and BLM lands removed).

Staff evaluated data in the WA Database to determine if the landslides on BLM and GDRC were also included in the ROWD Database. The comparison indicated:

- On BLM lands, 118 slides are identified in the WA Database with 99 (84%) identified in the ROWD Database. The slides not included in the Palco dataset were all initiated in 1997 and had a total discharge volume of 3,969 yd^3. This accounts for 15% of the total volume of sediment loading from shallow hillslope landslides on BLM lands in the WA database.
- On GDRC lands, 47 slides are identified in the WA Database with 36 (81%) identified in the ROWD Database. The slides not included in the dataset were all initiated in 1997 and had a total discharge volume of 40,048 yd^3. This accounts for 70% of the total volume of sediment loading coming from shallow hillslope landslides that are identified in the WA Database.

Neither the ROWD Database nor the WA Database included data for GDRC or BLM lands for the 2003 photo period. This likely results in an underestimation of sediment loading from the shallow hillslope landslide category for the 2001-2003 time periods in the South Fork Elk River subbasin, as well as within the McCloud Creek, Toms Gulch, and Railroad Gulch subbasins.

The total shallow hillslope landslide loading per subbasin for available photo periods is presented in Figure 4.7. Over the 49 year time period evaluated in this Source Analysis, a total of 486,915 yd^3 of sediment was delivered to the fluvial system from shallow hillslope landslides. The time periods with the greatest delivery were 1955-1966 (34% of the total) and 1988-1997 (48%). The subbasins receiving the majority of the landslide derived sediment were Bridge Creek (18%), Lake Creek (15%), North Branch North Fork Elk River (14%), Lower North Fork Elk River (12%), Upper North Fork Elk River (11%), and Lower South Fork (9%).

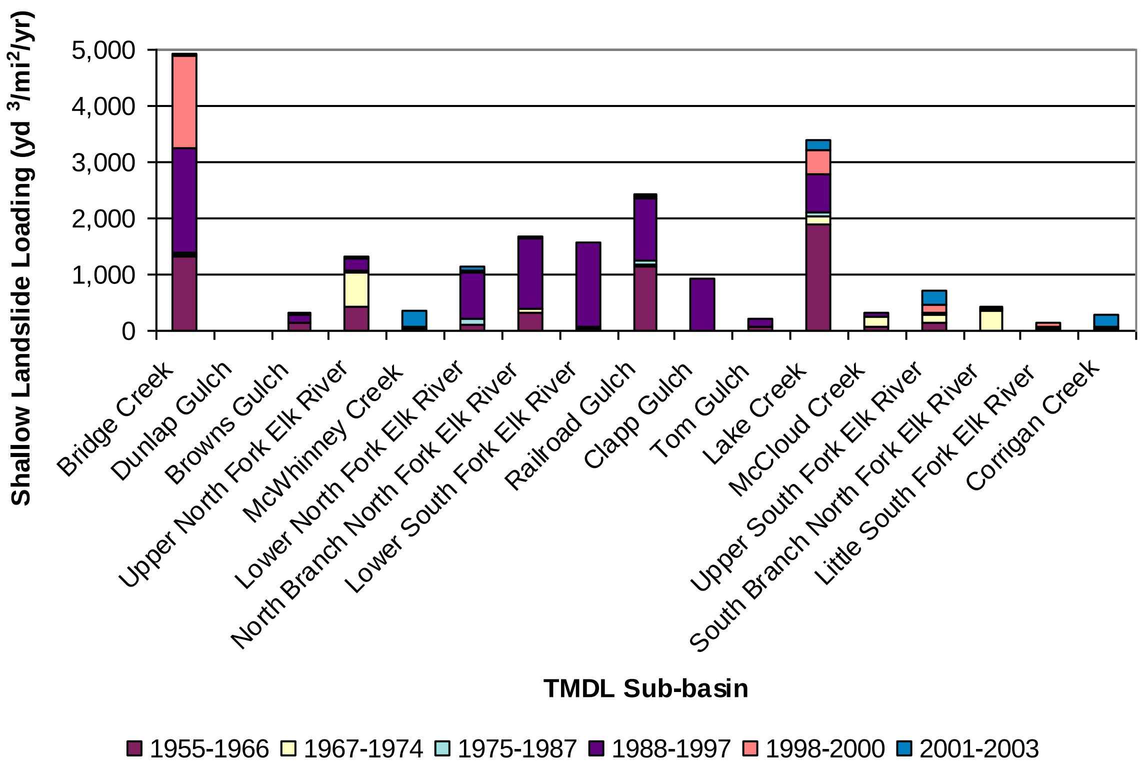

Figure 4.7 Annual average sediment loading from management-related shallow hillslope landslides by photo period and subbasin.

To provide further refinement on the analysis of sediment delivery from shallow hillslope landslides and to facilitate development of implementation actions designed to control these management-related discharges, the Source Analysis presented the available landslide data as either road-related or open-slope landslides. Open-slope landslides are those hillslope slides that cannot be attributed to the presence of roads or landings. The management-related portion of the slide is determined by subtracting the natural shallow landslide loading from the total open slope landslide loading. This Source Analysis presents the road-related and open-slope landslide data by ownership (Appendix 4F)and as a cumulative total for the watershed (presented in the following sections).

Road-Related Shallow Hillslope Landslide Analysis

The annual average sediment loading associated with road-related landslides on the dominant ownerships in the Upper Elk River is shown in Figure 4.8. From 1955-2003, a total of 209,635 yd^3 of sediment associated with these landslides was delivered to the fluvial system. The greatest sediment delivery was associated with the years 1955 to 1966 with 25% and 1988-1997 with 65% of the total delivery to the fluvial system. The subbasins receiving the majority of the road-related landslide sediment delivery were North Branch North Fork Elk River (25%), Lake Creek (22%), Lower North Fork Elk River (21%), and Bridge Creek (10%).

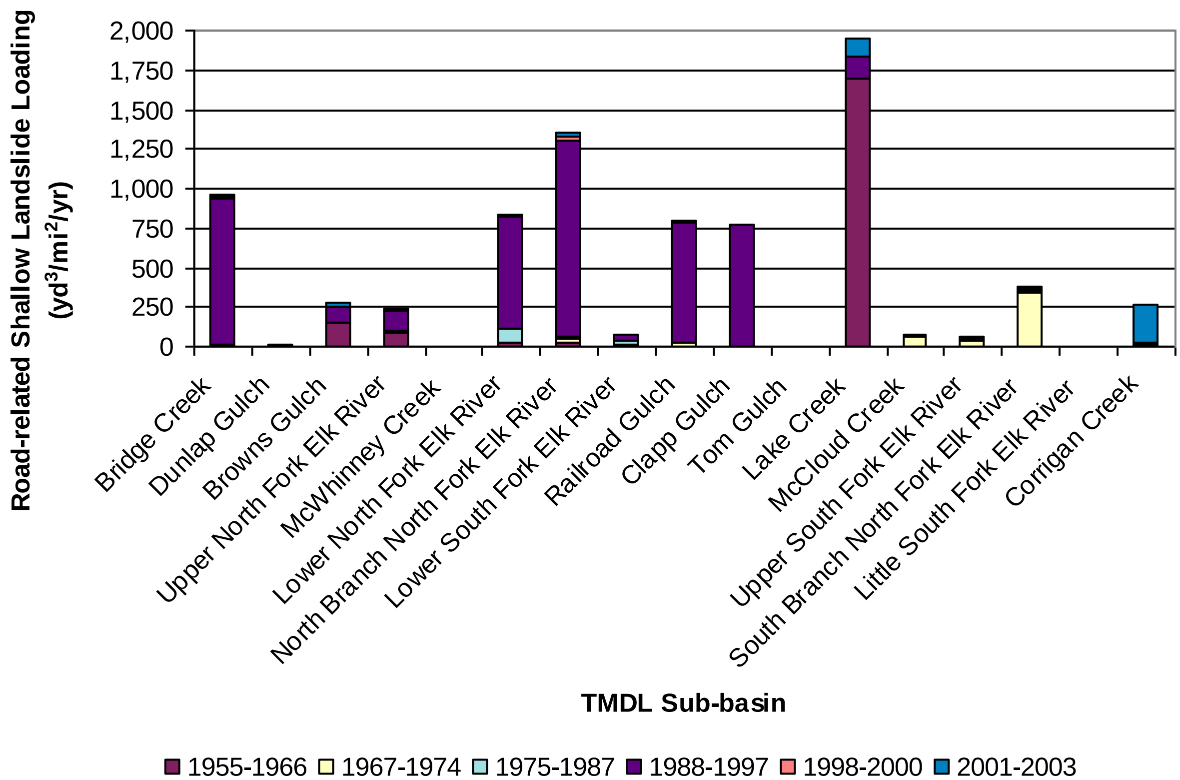

Figure 4.8 Annual average sediment loading from road-related landslides by photo periods for all dominant ownerships.

Table 4.9 presents the sediment loadings from road-related open-slope landslides to Upper Elk River as a whole.

Table 4.9 Annual sediment loading from road-related landslides in Upper Elk River ($yd^3/mi^2/yr$)

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Annual Road-related Landslide Loading in Upper Elk River ($yd^3/mi^2/yr$).	99	29	15	307	3	20

The incidence of road- related landslides can often be correlated to the design, engineering and construction techniques implemented by individual landowners. For this reason Regional Water Board staff evaluated the available road-related landslide data separately for each of the large ownerships (BLM, GDRC, and HRC). (See Appendix 4F).

<u>Management-Related Open Slope Shallow Hillslope Landslide Analysis</u>

Annual average sediment loading associated with open slope shallow landslides for the dominant ownerships in the Upper Elk River and South Fork Elk River is shown in Figure 4.9. From 1955-2003, a total of 277,280 yd^3 of sediment was delivered from open-slope landslide features. The time periods associated with the greatest percentage of the total sediment delivery were 1955-1966 (40%) and 1988-1997 (35%). The subbasin within the

Upper Elk River which received the majority of the sediment delivered from open-slope landslides were Bridge Creek (25%), Upper North Fork Elk River (16%), Lower South Fork Elk River (16%), Lake Creek (9%), and Upper South Fork Elk River (9%).

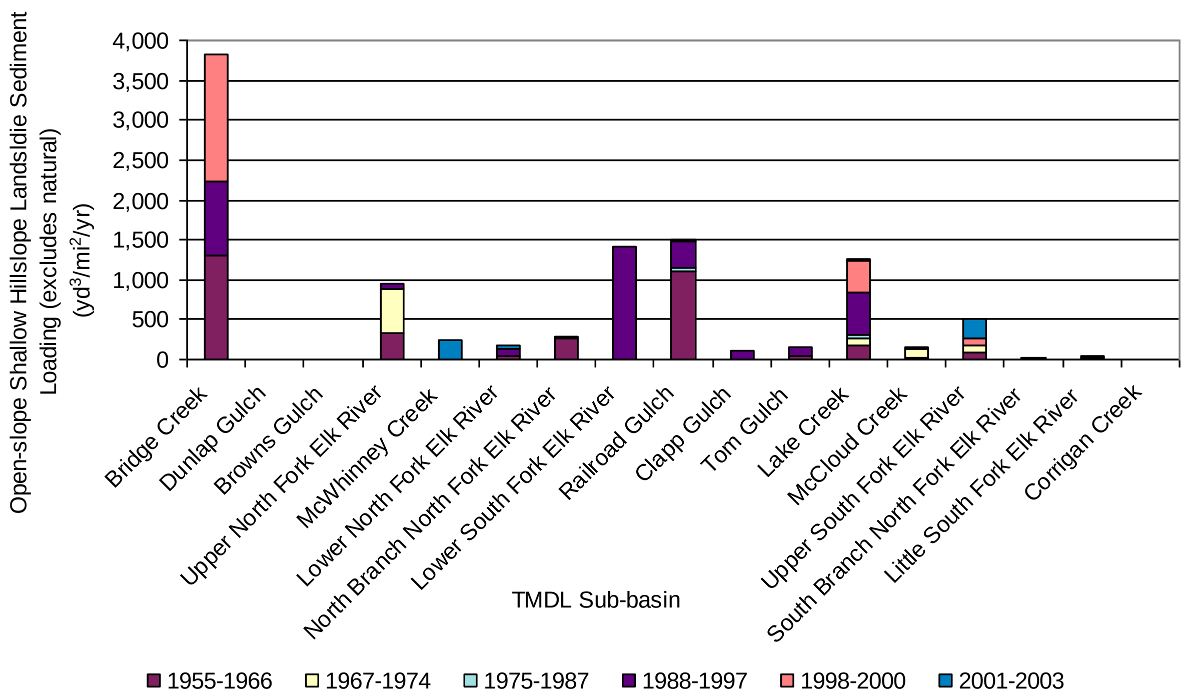

Figure 4.9 Sediment loading associated with open-slope landslides for all ownerships (excludes natural shallow hillslope landslide loading).

Table 4.10 summarizes the sediment loadings from management-related open-slope landslides to Upper Elk River as a whole.

Table 4.10 Annual sediment loading from open-slope landslides in Upper Elk River ($yd^3/mi^2/yr$)

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Annual management-related open-slope landslide loading in Upper Elk River ($yd^3/mi^2/yr$).	189	82	6	201	118	51

Open-slope landslide data was evaluated separately for BLM, GDRC, and HRC lands. (See Appendix 4F).

The following issues have been identified as containing a level of uncertainty that could affect the analysis of management-related shallow landslides (road related and open-slope):

- The estimates of delivery associated with landslide features identified on aerial photographs[56] are imprecise.

[56] Palco (2004).

- Stand age[57] is interpreted based upon the difference between the current stand age and the date of the aerial photo on which the landslide first appeared.
- Some portion of the open-slope landslides is influenced by skid trails that were not identified as part of the analysis.
- Interaction of earthworks (roads, skid trails, landings, etc.) was based on aerial photo interpretation without benefit of field verification.
- The actual dates of landslide initiation are unknown. Initiation dates were estimated using a time sequence series of aerial photos. Inferences may be made about the timing of large storm events and the likely initiation data.
- No landslide inventory was available for GDRC and BLM lands for the 2001-2003 photo period. This could result in a significant underestimation of the total loading for that time period in the subbasins which include BLM and GDRC ownership.
- Regional Water Board staff compared sources of landslide data including the ROWD Database, the WA Database, and the summary data from PWA (2001). In some cases, the ROWD Database did not include landslide volumes found in the other sources, indicating a potential underestimation of landslide related sediment loading. Table 4.11 summarizes the potential underestimation in landslide sediment loading. The biggest differences exist in areas of former Elk River Timber Company[58] ownership.
- Landslides were segregated by ownership based upon available mapping. There is uncertainty in the location of the landslide origin along ownership boundaries. Additionally, conditions on adjacent ownerships may affect landslides. The area most likely to experience influences from an adjacent ownership is along the South Fork Elk River in which BLM manages a 300-foot wide corridor on either side of South Fork Elk River.

Table 4.11 Potential underestimation of landslide loading based upon differences in the ROWD Database, WA Database, and PWA (2001).

TMDL Subbasin	Shallow hillslope landslide sediment loading ($yd^3/mi^2/yr$)				
	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000
Browns Gulch					67
Clapp Gulch		16	15	936	627
Dunlap Gulch			1		7
McWhinney Creek					4
North Branch North Fork			6		69
Railroad Gulch	882		99	517	447
South Branch North Fork	0			34	32
Tom Gulch		187	81	280	167

[57] Palco,(2004).
[58] Elk River Timber Company was a subsidiary of Sierra Pacific Industries. Their ownership in Elk River was transferred, largely to Pacific Lumber Company as part of the Headwaters Deal. A portion of their ownership is included in Headwaters Forest Reserve.

Upper North Fork Elk River			30	26	140
South Fork (includes Upper South Fork, Lower South Fork and Corrigan Creek)			9		

Stream buffers should be designed such that vegetation is maintained capable of capturing and minimizing landslide sediment and from which large wood may be delivered to the stream system. The identification, prevention, and control of landslides have been a major focus of landowners and the Regional Water Board throughout the Upper Elk River TMDL development process. This was a result of the recognized contribution that landslide delivery had on the overall sediment load in the Upper Elk River watershed. Efforts have been made to reduce the potential of management-related activities to affect landslide initiation and/or reactivation. These ongoing efforts include:

- Limitations on ground-based yarding activities and road construction on steep slopes and headwall swales.
- Identification of existing landslide features by trained professionals.
- Evaluation by Registered Geologists of proposed management activities (tree felling, road construction, etc.) on and adjacent to landslide features.
- Limitations on timber harvesting (felling and yarding of trees) on and adjacent to landslide features.
- Limitation on rate and scale of land disturbing activities in the subbasin.

Factors limiting the effectiveness of these efforts include:

- Poor resolution of topographic maps making site characterization difficult.
- Lack of comprehensive effectiveness monitoring program to quantify prevention efforts.
- Existing and persistent effects from management activities (e.g. increases in flow from upslope hydrologic alterations).

To address identified data gaps and provide a foundation for watershed implementation actions, Regional Water Board staff commissioned the development of two new datasets for use in the Elk River watershed. These datasets include:

- High resolution topographic mapping of the entire Elk River watershed.
- Landslide hazard mapping based upon the application and testing of probabilistic landslide hazard models. These efforts and resulting tools are described briefly. For more detailed information on the effort, the project reports (Sanborn, 2005 and Stillwater, 2005) are available for download[59].

First, topographic data (i.e. digital elevation model (DEM)) derived from LiDAR (Light Detection and Ranging) data were collected during March 2005. The resulting LiDAR DEM is useful for field and planning efforts for identifying landforms, management features (e.g.

59 <http://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/elk_river/ > (as of February 25, 2012.

roads and skids), watercourses (as employed in the channel incision surveys), channel slopes, etc.

Second, two distributed, physically-based models were selected for predicting potential shallow landslide hazards. These models were chosen based on their common usage and past performance in forested mountainous terrain: the deterministic model SHALSTAB (Montgomery and Dietrich 1994, Dietrich et al. 2001) and the probabilistic model PISA (Haneberg 2004, 2005). SHALSTAB is a physically-based, deterministic model that combines an infinite slope stability model and a steady-state hydrologic model to predict the potential for shallow landsliding controlled by topography and pore water pressure (Montgomery and Dietrich 1994, Dietrich et al. 2001). PISA is a physically based, probabilistic model that predicts spatially distributed static and seismic shallow slope stability for topography obtained from a digital elevation model and geotechnical information (Haneberg 2004, 2005). Two versions of each model were applied to Elk River to identify the relative landslide hazard. Staff intend the results to be integrated into a landslide hazard map for use by land managers and regulators when identifying/assessing the best management practices for implementing this sediment TMDL.

Hypothesis tests were developed to objectively validate model results and to evaluate the relative performance of the modeling approaches. Tests in different geologic terrains were conducted with the goal of evaluating the extent to which model performance and model threshold values vary across different geologic terrains. The testing results can be interpreted to identify model threshold values for which a defined percentage of landslides are expected to be included on a corresponding percentage of the landscape, thus informing beneficial use protection and economic tradeoffs. In areas over selected thresholds, management avoidance or mitigations can be employed.

The LiDAR DEM and landslide hazard map, in combination with existing landslide mitigations, are expected to improve identification of landslide prone areas and inform appropriate management strategies to ultimately prevent and control the sediment loading from management-induced shallow hillslope landslides.

Management-Related Streamside Landslides

As used in this Source Analysis, streamside landsides are landslide features that originate from streamside slopes and are too small to detect on aerial photographs. This source category includes those streamside landslides that were initiated as a result of management-related actions. As part of this TMDL development effort, PWA (2006) conducted aerial photo and field-based comparisons in three areas (Study Subbasin approach) of different timber stand ages, including old-growth, advanced or mature second growth (stand age >30 years), and young forest (stand age <30 years). These inventories formed the basis for developing the estimate of sediment delivery associated with streamside landslides. Comparison is made with Palco Watershed Analysis estimates (Palco, 2004) of sediment loading. Additionally, to inform the magnitude of delivery associated with earlier time periods, staff compared streamside landslide loading estimates with those of open-slope landslides.

Appendix 4E describes the field methods used to collect data for both the old-growth reference subbasin, Upper Little South Fork Elk River, as well as a description of the field efforts to develop data for the other forest types. The management-related streamside landslide analysis relies on the old-growth data as well as data from the advanced second growth and young stands. Figure 4.10 displays the streamside landslide survey areas. The old-growth sample area is located in Little South Fork Elk River reference study subbasin, the advanced second growth area is located in Upper Freshwater Creek and the young forest area is located in Little Freshwater Creek.

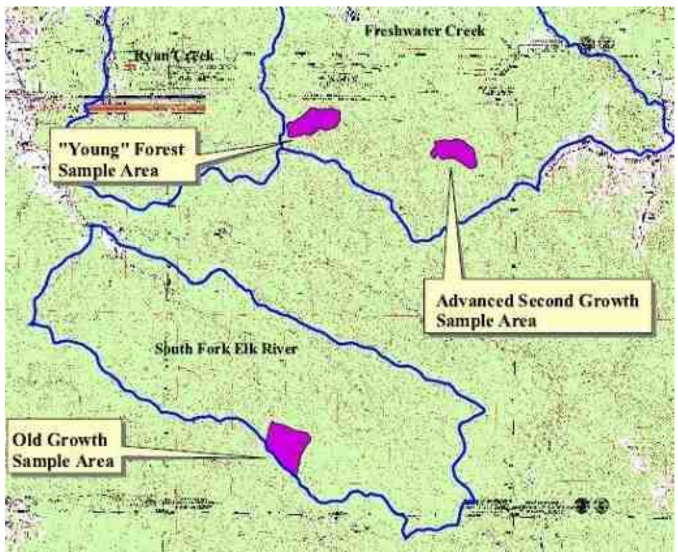

Figure 4.10 Locations of the streamside landslide study areas. (PWA, 2006).

PWA (2006) reported the number of slides in the small and large categories (less than and greater than 5yd^3, respectively) and provided an estimate of the total volume of large slides for each of the corresponding photo periods (1975-1987, 1988-1997, 1998-2003). Regional Water Board staff calculated the average slide volume for each of the different forest types and applied that average volume to the number of slides per photo period. This approach was used to estimate the volume of sediment delivery associated with the different photo periods in the different forest types. Regional Water Board staff also assumed that the proportion of the small slides per photo period to the total small slides, for each area, was consistent with that of the large slides.

Table 4.12 presents the results of the field surveys conducted to collect data relative to this source category. The results indicate that as forest age decreases, the number of small and large landslides increases, as does the average large slide volume.

Table 4.12 Survey results from streamside landslide survey (PWA, 2006).

Forest Type	Unmanaged Old growth[1]	Advanced Second Growth	Recently Harvested Areas
Watershed	Little South Fork Elk River	Upper Freshwater Creek	Little Freshwater Creek
Length of inventoried stream channel (miles)	2.5	3.2	3.3
No. large (>10yd³) / small (<10yd³) landslides[2,3]	7 / 7	15 / 14	21 / 27
1975-1987 (13 years)		3 / 2.8	2 / 2.6
1988-1997 (10 years)		9 / 8.4	11 / 14.1
1998-2003 (5 years)		3 / 2.8	8 / 10.2
Volume Sediment delivered from large landslides (yd³)	308	1056	4791
Average volume per larger slides (yd³/slide)	44	70	228
Volume sediment delivered from small landslides (yd³)[4]	35	70	135

[1]Numbers reflect adjusted survey described in Section 4.3.
[2]Totals for all photo periods.
[3]Assuming the proportion of the small slides per photo period to the total small slides, for each area, was consistent with that of the large slides.
[4]Assuming an average small slide volume of 5 yd³.

Because the spatial age distribution of riparian stands is unknown, Regional Water Board staff assumed that management-related streamside landslides in Elk River followed a pattern indicated by pooling the data from the advanced second growth and recently harvested areas (Table 4.13). This assumption likely over estimates the age of riparian stands throughout portions of the Upper Elk River watershed, resulting in an underestimate of the streamside landslide loading in those younger stands. Similarly, using the average of the two managed forest types will result in an overestimate of delivery in older areas.

Table 4.13 Combined results for delivery per channel length for recently harvested (<30 year stands) and advanced second growth (> 30 years stands).

	Number of large / small[1] slides in managed areas[2]	Average volume per large / small slide (yd³/LS)	Annual unit delivery from large / small slides in managed areas (yd³/mi/year)	Total annual unit delivery from small and large slides in managed areas (yd³/mi/year)
1975-1987 (13 years)	5 / 5.69	162 / 5	9.6 / 0.3	9.9
1988-1997 (10 years)	20 / 22.78		50.0 / 1.8	51.7
1998-2003 (5 years)	11 / 12.53		55.0 / 1.9	56.9

[1]Assuming the proportion of the total small slides per photo period is the same as that of the large slides.
[2]Combined survey length of 6.5 miles

Staff evaluated the *Elk River Watershed Analysis* (WA) (Palco, 2004) which presented results from streamside landslide surveys conducted in North Fork Elk River[60]. The WA

60 Section A.7.2 Small Streamside Landslides.

estimated streamside landslide loading for the 1988-2000 photo period from all streamside landslides not documented on the PWA aerial photograph landslide inventory (WA Database), attributing all non-road streamside landslide loading to natural sources. The WA surveys were conducted in three areas of North Fork Elk River. Table 4.14 presents the results from the WA surveys which included data collected along Class I and Class II watercourses. Class III streams, which the WA indicates comprises about two-thirds (62%) of the total channel length in the 44 mi^2 watershed assessment area, were not included in the WA survey (Appendix 4C, Table 2).

Table 4.14 Palco Watershed Analysis streamside landslide survey results for photo period 1988-2000 (Palco, 2004).

Stream Class	Survey Length (ft)	Number Landslides per 3300' of channel	Volume per Landslide (yd^3/LS)	Volume per channel length (yd^3/mi)	Volume per channel length (yd^3/mi/yr)	Drainage Density (mi/mi^2)	WA Annual Loading (yd^3/mi^2/yr)
Class I	6400	7.7	128	1577	121.30	1.07	130
Class II	2800	10.8	68	1175	90.39	2.02	183
Total CI and CII:	9200	Average = 9.3	Average = 98		Average = 100.86[1]	3.10	313

[1]Weighted average based upon percentage of total stream length comprised by stream class.

The WA streamside landslide surveys indicate a greater annual unit delivery than the PWA survey results, likely because the PWA surveys were not limited to Class I and II watercourses. It is expected that within the expanded network, as stream power decreases with decreasing drainage area, the volume per slide and the slide frequencies also is expected to go down.

Application of the PWA survey results to the current drainage network estimates results in an unreasonably high loading estimate for streamside landslides in Regional Water Board staff's judgment. This is likely due to the extent of the current drainage network, much of which is comprised of watercourses with low stream power where loading associated streamside landsliding is expected to be much less than larger watercourses.

In this Source Analysis, Regional Water Board staff calculated the streamside landslide loading within the natural drainage network based upon the PWA survey results. Within the expanded network, the slides are expected to be smaller and less frequent and Regional Water Board staff assumed that the small streamside landslides are accounted for in the stream bank erosion estimates as described above.

For the purposes of developing streamside landslide loading estimates for analysis time periods before 1975, Regional Water Board staff conducted a comparison of the streamside landslides and open-slope landslides. For the period of 1975-2003, corresponding to the streamside landslide surveys, the total delivery associated with small streamside landslides in managed areas was 988 yd^3/mi. For the same period, the total delivery from open-slope landslides was 18,891 yd^3. Regional Water Board staff assumed the ratio of small streamside landslides to open-slope landslide delivery for the 1975-2003 period was constant for all photo periods. Those results indicate a much lower estimate of streamside landslide loading for the 1975-1987 period, a similar loading for the 1988-1997 period, a higher estimate for the 1998-2000 period, and a loading in 2001-2003 similar to that of 1988-1997. This method allows for estimation of streamside landslide loading for the earlier time periods (1955-1974) for which open-slope landslide estimates are available but not streamside landslide estimates.

For the purposes of this sediment source analysis, within the natural drainage network, Regional Water Board staff relied on the streamside sediment delivery estimated by PWA for the 1975-2003 time periods, and the estimates based upon the ratio of streamside to open-slope landslides for the 1955-1974 time periods. The management-related streamside landslide loading was calculated as the total loading for the managed areas minus the natural loading of 26 $yd^3/mi/yr$. Figure 4.11 presents the resulting management-related streamside landslide loading.

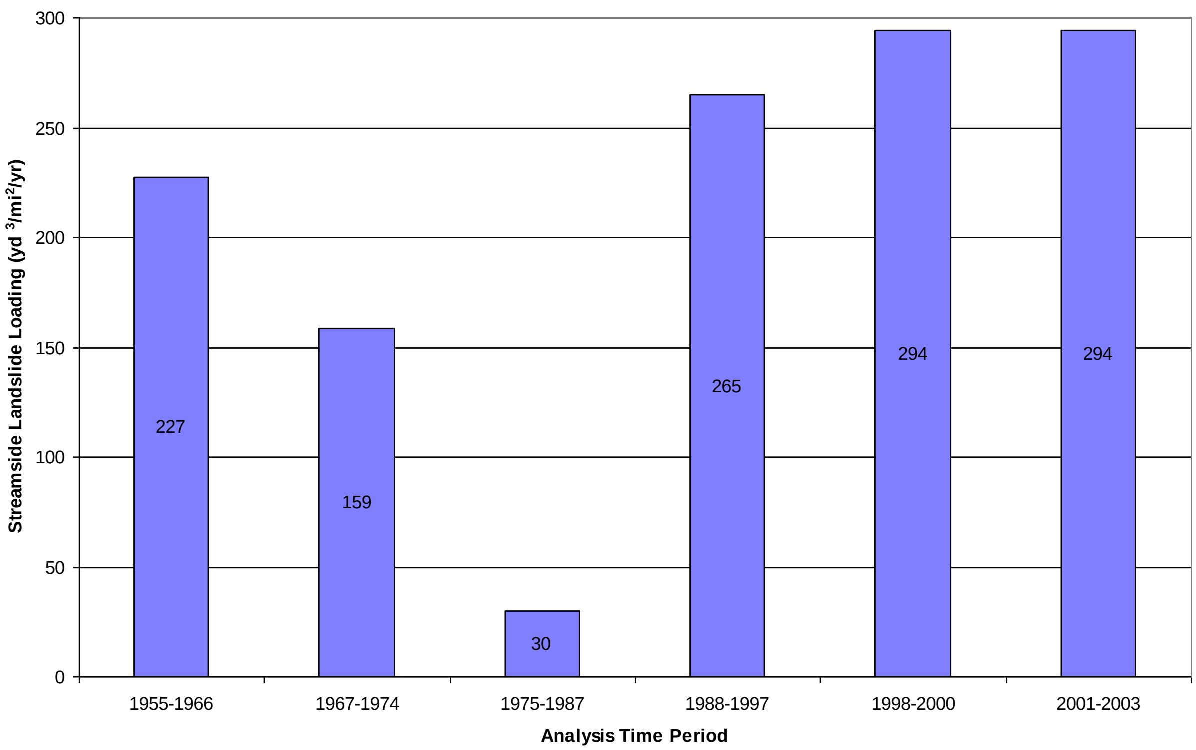

Figure 4.11 Annual average sediment loading from management-related streamside landslides.

The following issues have been identified as containing a degree of uncertainty that could affect the analysis of management-related streamside landslides:

- Characterizing the age of features can be difficult, contributing to uncertainty associated with assigning a time period to the streamside landslides. Specifically, smaller features get masked over time, thus smaller older features may be missed in the inventories. Additionally, if features reactivate, they may be attributed to the time period associated with reactivation and the original feature may not be included in the earlier time periods.

- The estimation of the streamside landslide loading associated with the 1955-1966 and 1967-1974 time periods are subject to greater uncertainty due to reliance on the ratio with open-slope landslide loading. It is likely that the earlier time periods have a higher loading from small streamside landslides due to the lack of stream buffers and the use of streams as yarding corridors.
- These estimates do not account for channel storage or routing through the system.
- Uncertainty is associated with staff's assumption that the rates of natural and management-related streamside landslides, as determined within the sample reaches are applicable to the Upper Elk River watershed as a whole.
- PWA (2008) data did not include an estimate for the time period associated with delivery from small streamside landslides. For this analysis, Regional Water Board staff assumed that the relative proportion of delivery from small landslides within each photo period was the same as for large landslide features.
- Staff calculated an average volume of sediment per large slide for each of the sample areas and applied that volume across each of the photo periods. There is uncertainty associated with this assumption as land management changes or storm magnitude could have a big effect on slide volume.
- The management-related streamside landslide rates are based upon combined data for the recently harvest and advanced second growth. The decision to represent managed areas by one rate was made due to the lack of a comprehensive, spatial representation of harvest history and the resulting stand age. Harvest history, including silvicultural and yarding techniques, and the level of riparian protections influence streamside landslide loading.

Discharge associated with management-related streamside landslides may be controlled by:

1) Avoiding additional management related headward channel incision.
2) Promoting stable channels in equilibrium by reducing sediment loading and enhancing structural stability.
3) Limiting hydromodification from timber harvesting and road influences to prevent additional scour.
4) Promoting hillslope stability by maintaining adequate stand volumes to decrease slide frequency and volume as slide frequency and volume increases in younger stands (Table 4.12). Providing protective stream buffers of adequate width and vegetative condition to minimize sediment delivery from streamside landslides that do occur.

Management-Related Discharge Sites

Discharge sites are defined as erosion features that discharge (or have the potential to discharge) sediment in violation of applicable water quality requirements, are caused or affected by human activity, and will respond to management measures. This definition is synonymous with "controllable sediment discharge site" as used in the timber-related waste discharge requirements adopted by the Regional Water Board for the Elk River watershed (NCRWQCB, 2004). By definition, some treatment is possible at these management-related sites. Discharge sites include sites associated with watercourse crossings, roads, skid trails, gullies, road-related and non-road-related landslides. Typically these sites are treated by removing some volume of fill material and then treating the channel and excavated slopes to minimize post-treatment sediment delivery. Double counting of discharge sites are avoided by removing road and non-road landslide features from the databases, as they are included in the management-related shallow landslide categories.

Significant progress has been made in identifying, prioritizing, treating and monitoring these sites in Elk River. On HRC ownership in the Upper Elk River, the program is implemented through a series of CAOs [61] and on a THP by THP basis, pursuant to enrollment under their Watershed-wide Waste Discharge Requirement (WWDR)[62]. The program on GDRC lands is implemented on a THP by THP basis pursuant to their WWDR[63]. On land controlled by the BLM, the program is implemented through the Headwaters Forest Management Plan[64]. On non-industrial timber lands the program is implemented within THP[65] and Non-Industrial Timber Management Plans (NTMP) [66] harvest areas and roads appurtenant to the harvest operations. The data available for this sediment source analysis reflects the status of the program to date. Where property-wide programs are in place, relatively complete data sets are available. Where no property-wide program is in place, robust data sets are unavailable.

The following sections present information by ownership to reflect the differences in the available datasets. Data are presented to quantify, over time, the past sediment loading associated with discharge sites, the treatment progress to date, and potential future delivery from the sites.

Discharge Sites on Humboldt Redwood Company Lands

The Elk River property-wide programs for inventory, prioritization, and treatment of discharge sites began on Humboldt Redwood Company (HRC) property in Elk River in 1997[67]. As a result, available data are much more extensive on HRC lands than other ownerships in the watershed.

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[61] Order No. R1-2004-0028 (South Fork Elk River and Mainstem Elk River) and No. R1-2006-0055 (North Fork Elk River) (as amended by Order No. R1-2008-0100 to reflect new ownership).

[62] Order No. R1-2006-0039 (as amended by Order No. R1-2008-0100 to reflect new ownership).

[63] Order No. R1-2006.-

[64] The United States Department of the Interior, Bureau of Land Management and California Department of Fish and Game Management Plan for the Headwaters Forest Reserve (2003).

[65] Order No. R1-2004-0030, and Order No. R1-2009-0038.

[66] Order No. R1-2009-0038.

[67] Order No. R1-1997-0115

The Elk River Watershed Analysis (WA) sediment budget and the aerial photo analysis landslide data (Palco, 2004b) (WA Database) were used to develop loading values for this source category. This data set includes landslide feature data and attributes for 856 discharge sites on Palco (now HRC), BLM, and GDRC lands identified on 1954-2000 aerial photos. It includes estimates of past delivery for these landslide features.

1. The Palco Elk River WA sediment budget road database (WA Road Database) (Palco, 2004c) identified discharge sites related to stream crossings, stream banks, road gullies, cut bank, fillslope, road and ditch, torrent track, and hillslope debris features. The WA only reported the inputs for the 1990's. This Source Analysis evaluated discharge sites by delivery volume per decade (beginning in 1955). The data was based upon field and aerial photo descriptions and presented by subbasin. A total of 1,346 sites are included in the database, including 476 sites not included in the WA Landslide Database.
2. Field surveys of discharge sites in South Fork and Mainstem Elk River (PWA, 2001)[68] inventoried the entire road system to identify road-related sites of past erosion and sediment delivery. An air photo inventory was also performed to identify non-road and road-related shallow landslides (and estimated sediment delivery volumes) using historic aerial photos from 1954, 1966, 1974, 1987, and 1997. Summary tables of preliminary estimates of past erosion and delivery from non-road debris landslides and debris torrent sources and road-related sources for the analyzed areas by photo period (for landslides) and by decade (for field inventories) were made available to Regional Water Board staff. Skid trail-related landslides were classified as non-road-related landslides, while railroad-related landslides were classified as road-related landslides. A total of 829 sites were identified and summary information provided.
3. CAOs required the development of a CAO Database[69] which included the inventory, prioritization, treatment, and reporting of sediment discharge sites. Data relative to past delivery was not required under the CAO requirements and as such this information is not reflected in the database. Additionally, no discharge sites in the Clapp Gulch subbasin are included in the database, likely in part because those areas were transferred to Pacific Lumber Company as part of the Headwaters Deal and treatments were conducted there prior to the South Fork inventories being made. A total of 1,425 sites are in the CAO Database[70].
4. The Palco ROWD Landslide Database (Palco, 2005) was developed and submitted to the Regional Water Board staff as part of the Final Palco Report of Waste Discharge (ROWD). The database is a compilation of all available earlier databases, with the addition of landslides identified on the 2003 aerial photos. The database contains attributes for 1,144 landslides.

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68 Memo dated December 10, 2001, To: Matt O'Connor, OEI, From: Eileen Weppner, PWA, subject: Road-related and non-road related erosion and sediment delivery to Clapp Gulch, Railroad Gulch, South Fork Elk River, and lower Mainstem Elk River (interfluves).

69 CAO No. R1-1997-115,;CAO No. R1-1998-100,; CAO No. R1-2002-0114; CAO No. R1-2004-0028; CAO No. R1-2006-0055.

70 2010 Elk River Inventory Update.

For the purposes of this sediment source analysis, both past and future sediment delivery are of interest; past, such that a source analysis could be constructed and future, to guide ongoing watershed implementation actions. The WA Road Database was used to quantify past sediment delivery and the CAO Database was used to determine future sediment delivery. Because none of the data sources appear wholly comprehensive, nor do their attributes fully coincide, Regional Water Board staff evaluated the maximum differences in sediment loading based upon all the available data sources and expressed the differences in terms useful in the development of a margin of safety.

The WA Road Database was analyzed for past sediment delivery (1950-2000) associated with discharge sites. The Palco ROWD Landslide Database was used to characterize shallow hillslope landsliding. To avoid double counting, sites in the WA Road Database were compared with the ROWD Landslide Database and the duplicate landslide sites were removed from the WA Road dataset.

The subbasin names and delineations presented in the WA differed slightly from the subbasins defined in this Source Analysis. To facilitate analysis of the data, the subbasin delineations/names were modified to be consistent with those used here. For example, the WA did not include Corrigan Creek as a separate subbasin, as it was included as part of the WA's South Fork subbasin. For consistency, the South Fork basin is referred to as the Upper South Fork, Mainstem was renamed Lower Elk River, and North Fork was renamed Upper North Fork. The Lower North Fork and Upper North Fork were combined and renamed Lower North Fork.

The data were then sorted by subbasin and sediment delivery by decade was determined as a sum of the sites. A number of the sites did not have dates associated with the past yield estimates. In this case, the sediment delivery was distributed evenly over the decades following the date of construction.

The average sediment delivery per year was determined by dividing the decade associated with the erosion by 10 years. In the case of the 1950's, the first erosion and road construction was associated with the 1954 photos, thus the value was divided by 5 to represent the 1955-1959 time period.

In addition to the WA Road Database, the summary of South Fork and Mainstem discharges (PWA 2001) was used for those areas included in that analysis. The non-landslide data were selected, including: stream crossing washout, gullies (fillslope/hillslope/road), and stream bank erosion. The sediment delivery per year was similarly determined from the decadal data.

Discharge Sites on Green Diamond Resource Company Lands

As part of their Elk River WWDR[71], Green Diamond Resource Company (GDRC) is scheduled to have all discharge sites inventoried and treated on their ownership by 2015.

[71] Order No. R1-2006-0043.

To that end, GDRC inventoried their ownership for road-related sites with potential for future sediment delivery. The findings were documented in PWA (2006). In addition to the road inventory, and scheduling and treatment of sites identified therein, the WWDR requires that all areas in the watershed be inventoried and treatment of discharge sites implemented. To ensure all discharge sites are identified and treated, the WWDR alo required GDRC to address non-road related discharge sites, both within and beyond THP boundaries.

Data sources used to determine sediment loads from discharge sites on GDRC lands include:

1. 2006 GDRC Road inventory[72]. Pursuant to the WWDR requirements, a complete road survey was conducted on GDRC lands. It includes a written report and excel database of sites. A total of 151 sites are included in the GDRC Road Inventory Database. Attributes include past and future delivery volumes, as well as treatment priority.
2. GDRC Master Treatment Schedule[73]. Also pursuant to the WWDR requirements, GDRC developed a schedule for all inventoried sites.
3. GDRC Annual Reports[74]. Pursuant to the WWDR requirements, annual reports describing status of site treatments and inventories of non-road areas are submitted annually to the Regional Water Board.
4. Palco WA Landslide Database. Includes a total of 47 slides are on GDRC property for the period 1954-2000.

Regional Water Board staff reviewed the GDRC Road Inventory Database for data relative to past and future sediment delivery. Additionally, Regional Water Board staff reviewed the GDRC Annual Reports to assess information regarding non road-related sources. Based on the review of the GDRC Annual Reports, no additional sites were encountered from 2007-2009. Regional Water Board staff did not include additional volumes to account for areas not yet inventoried.

Regional Water Board staff compared the GDRC Road Inventory Database numbers to the GDRC Master Treatment Schedule map to determine the location of sites by subject subbasins. The time period associated with past erosion was not attributed for all sites. In such cases, staff assumed a time period based upon 1) the time period of construction, and 2) time periods associated with other sites along the same road segments. Generally the time periods assigned for past erosion are decadal. These were then converted to the TMDL analysis photo periods for consistency with other source categories.

The GDRC Master Treatment Schedule includes sites that are not found in the GDRC Road Inventory Database. In this case, staff added the mapped sites into the database. For these sites, staff assigned "erosion priority", "past delivery volume", and "future delivery

72 Road Inventory for GDRC Lands in South Fork Elk River (PWA, 2006).
73 Master Treatment Schedule for South Fork Elk River (GDRC, 2007).
74 Completed Annual Summary Report for South Fork Elk River (GDRC 2007, 2008 and 2009).

volume", based upon evaluation of the other sites in the database. Table 4.15 presents the characteristics of the discharge sites recorded in the database.

Table 4.15 Discharge site characteristics on GDRC lands[75].

Erosion Priority	Future Delivery (years)	Number of Sites	Percent of Total Sites Assigned Priority	Average Past Sediment Delivery (yd^3)	Average Future Sediment Delivery (yd^3)	Ratio of past: future delivery
H	5	24	17%	159	363	0.44
HM	10	30	22%	55	324	0.17
M	20	31	22%	63	319	0.20
LM	30	41	29%	37	185	0.20
L	50	13	9%	48	60	0.79
	Erosion Priority Weighted Average = 21	Total=139	Total=100%	Erosion Priority Weighted Average = 69	Erosion Priority Weighted Average = 264	0.26

Determination of past and future volumes was made by calculating the average past and future erosions, weighted by the percent of total sites within assigned priority groups. The resulting volumes were estimated as 69 yd^3 average from past erosion and 264 yd^3 from future delivery. These volumes were assigned to sites where no volume data was included in the database. An erosion priority of "moderate" was assigned to sites where no priority had been assigned.

According to the report submitted as part of the GDRC Roads Inventory (PWA, 2006), 24 road-related landslides are included in the dataset. However, the GDRC Roads Inventory Database does not describe site type. The Palco WA Landslide Database includes 58 landslides on GDRC property, including 8 road-related landslides. In an attempt to avoid double counting, Regional Water Board staff assumed the road-related landslides in the HRC ROWD Landslide Database were included in GDRC Road inventory. Staff only included open-slope landslides from the landslide Database for GDRC lands in the landslide analyses.

Discharge Sites on Bureau of Land Management Lands

The Bureau of Land Management (BLM) acquired the Headwaters Forest area in 1999. The discharge sites on those lands were created before the land transfer occurred and are not reflective of BLM management. As part of the Headwater Forest Management Plan, BLM has a program to identify and treat discharge sites.

Data sources used to determine sediment loads from discharge sites on BLM lands include:

1. *2000 Headwaters Watershed Assessment*[76]. The written report summarizes PWA's erosion inventory and a plan for decommissioning the Worm Road in Upper Little South Fork Elk River. It includes a reconnaissance assessment of 3.6 miles of roads

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75 Based upon the Road Inventory Database for GDRC Lands (PWA, 2006).

76 Pacific Watershed Associates, Headwaters Watershed Assessment. Prepared for BLM. (2000)

and a sample of skid trails in recently harvested areas of Elk Head Springs in the Upper South Fork Elk River. The assessment was designed to identify treatable non-road erosion problems that would otherwise be missed in an inventory of road related erosion and to determine the relative importance of both sources of sediment production and delivery (PWA, 2000).

2. *2002-2004 Road Assessment*[77]. The written report summarizes 1) a complete inventory of all future road-related sediment sources on roads within the lands now under BLM management, and 2) a decommissioning plan, including methods and estimated costs, for erosion prevention projects and for re-contouring (outsloping) most roads in the project area. The assessment identifies all recognizable current and future sediment sources from roads in Little South Fork and along the riparian corridor in upper South Fork Elk watershed. The erosion potential and future delivery volume was estimated for each site (PWA, 2004).
3. *2004-2005 Road Treatment Summaries*[78]. The report describes the schedule, as of 2005, to treat the inventoried erosion sites identified in the 2002-2004 Road Assessment (PWA, 2005a).
4. *BLM Site Treatment Database*[79]. This electronic data from BLM reports treatment summaries: site number, treatment status, and potential future delivery volume from treated sites. No past sediment delivery was estimated.
5. *Palco WA Landslide Database*. This database includes a total of 118 slides on BLM property for the period 1954-2000.

The BLM Site Treatment Database containing the treatment status of sediment discharge sites and the 2002-2004 Elk River Road Assessment were used as the basis for quantifying sediment discharge sites on BLM lands. Estimates for sediment volume saved (prevented from delivery to the stream system) and treatment year were gleaned from the Site Treatment Database for all sites treated between the years 2000 to 2010. The treatment priority for treated sites was obtained from the 2002-2004 Road Assessment[80]. Time periods of potential future sediment delivery were assigned to each site based upon the identified erosion potential.

Regional Water Board staff estimated the past sediment delivery for each site based upon the 2000 Headwaters Watershed Assessment, in which the documented average past delivery was 13% of the future delivery volume. Regional Water Board staff also assumed the time period associated with past sediment delivery was associated with disturbance in different areas of the Headwaters Forest Reserve, informed by the Headwaters Forest Management Plan (BLM, 2003), 2000 Headwaters Watershed Assessment, 2002-2004 Road

77 Pacific Watershed Associates. 2004. 2002-2004 Road Assessment and Restoration Plan, Headwaters Forest Reserve. Agreement No. 1422-BA-0026, Task Order No. 4. Prepared for Pacific Coast Fish and Wildlife and Welands Restoration Association and the BLM

78 Pacific Watershed Associates. 2005a. Final Report 2004-2005 South Humboldt Bay Coastal Resources Protection Project, Salmon Creek and South Fork Elk River Watersheds. State Water Board Agreement #03-211-551. Prepared for State Water Board and BLM.

79 BLM. 2010. Spreadsheet database of site implementation for Headwaters Forest Reserve.

80 Table 2.

Assessment and discussions with BLM staff (pers. comm. Sam Flanagan, 2011). The time period used to estimate disturbance and associated sediment delivery with sites in the following subbasins include:

- Lower Little South Fork (1960, 1970, and 1990);
- Worm Road (1990); and
- Lower Elk River and Upper South Fork (uniformly distributed over the 1950s-2000s).

To ensure that past sediment delivery from shallow landslides were not double counted in the discharge sites and shallow hillslope landslide sediment source categories, landslides were not included in past sediment delivery in this landslide source category.

Summary of Results for Cumulative Loading from Discharge Sites on Dominant Ownerships (1955 to 2003)

The ownership-specific past sediment loading associated with management-related discharge sites were summed for each of the seventeen subbasins. The results are presented in Figure 4.12.

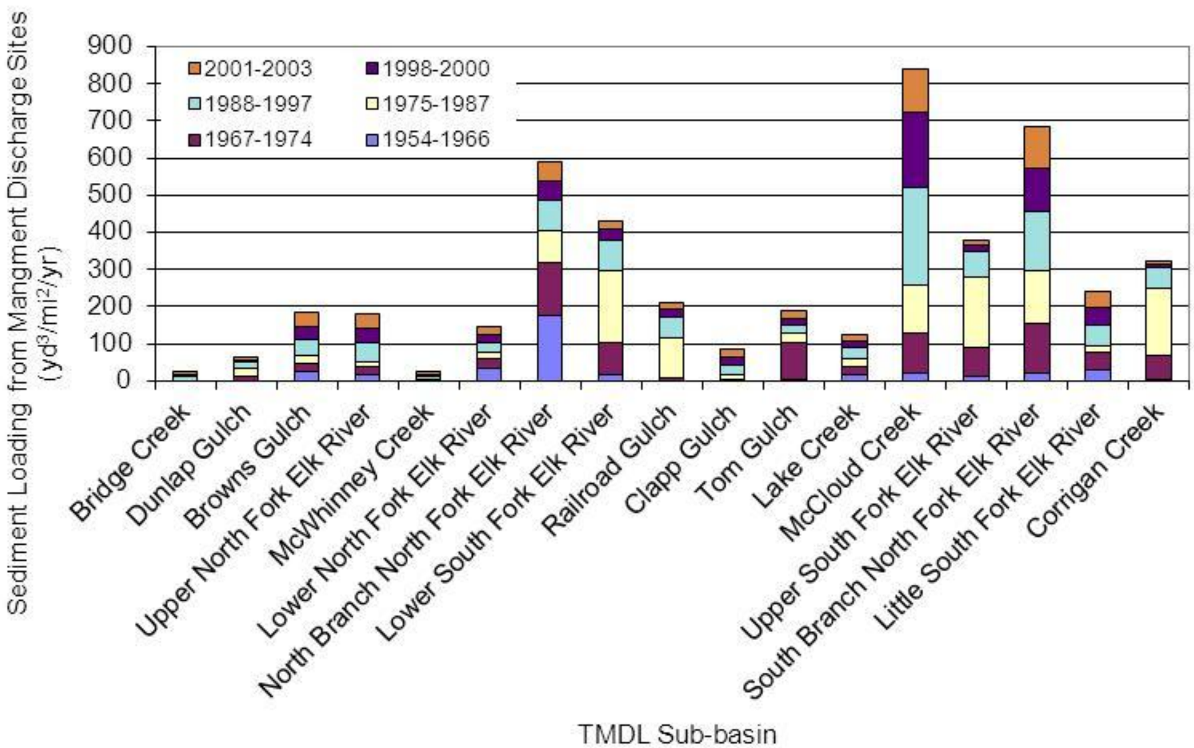

Figure 4.12 Annual average past sediment loading from discharge sites for dominant ownerships in Upper Elk by subbasins.

Table 4.16 presents the sediment loadings from management-related discharge sites to Upper Elk River as a whole.

Table 4.16 Annual sediment loading from management-related discharge sites in Upper Elk River ($yd^3/mi^2/yr$)

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Annual loading from management-related discharge sites in Upper Elk River ($yd^3/mi^2/yr$).	30	60	80	65	39	39

The following issues have been identified as containing a degree of uncertainty that could affect the analysis of management-related discharge sites:

- Not all areas of HRC's ownership in Upper Elk River have been fully inventoried, thus the available data are unlikely complete. Data updates will continue to occur as additional inventories are conducted and updates should be included in the CAO Database. Until a complete inventory is available, the past delivery estimates will be underestimated.
- Of the available data sources covering HRC lands, there are inconsistencies in the included areas, number of sites, time periods, and past and future delivery attributes. HRC has attempted to rectify these differences under the ROWD Database and CAO Databases. Despite these efforts, some uncertainty remains with the past and future delivery estimates from these sites.
- Assumptions about past and future delivery volumes may affect the estimates.
- There is uncertainty about the accuracy of the past and future delivery estimates.
- An ownership landslide inventory has not been developed for BLM lands. Thus landslides identified on BLM lands included in the WA inventory[81] are assumed to be representative.
- The discharge site data for BLM lands lack site-specific field estimates of past delivery volume. The average ratio of past to future erosion volume is assumed to be representative.
- The discharge site data for BLM lands lack time period estimates of past sediment delivery. The time period for past erosion was assumed based upon staff's estimates of disturbance throughout the BLM lands.

Factors that can reduce sediment discharge from discharge sites include:

1) Avoid creation of new sites through avoidance of substantial earthworks (cut and fill) near watercourses, including stream crossings, and the concentration of overland flow (e.g. road and skid trial runoff).
2) The cumulative future delivery estimates from discharge sites should be considered in prioritizing and scheduling site treatment.

Post-Treatment Discharge Sites

Decommissioning and upgrading of roads and stream crossings is recognized as important in preventing and minimizing large scale episodic sediment delivery. However, depending on site conditions, storm magnitude and timing, extent of site characterization and

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[81] Palco (2004b).

implementation techniques, there may be short-term adjustments and sediment delivery associated with road and stream crossing decommissioning and upgrading activities. The post-treatment discharge site source category captures these sediment inputs into the stream system.

Sediment discharges from treated sites can come in many forms, including but not limited to, channel scour, bank slumps, headward extension of nick points, culvert outlet and inlet scour, and surface erosion.

Stabilization of discharge sites, whether corrected with heavy equipment or hand-crews, often require additional surface and channel treatment in the form of mulching of exposed soils and armoring of channel and fillslopes to minimize sediment delivery due to post-treatment adjustment. Individual site conditions and operator experience heavily influence the magnitude of post-treatment erosion volumes. Several studies have been conducted on the North Coast to inform the magnitude of sediment discharged from this post-treatment related source (Table 4.17). From these studies, the combined average sediment delivery per treated site was 36 yd^3.

Table 4.17 Treatment-related sediment discharge volumes from north coast studies.

Study	Location	Average Delivery per Treated Site (yd^3)
Bloom (1998)[82]	Bridge Creek	113
Klein (2003)	Upper Mattole River	16
Klein (1984)[83]	Redwood National Park - small stream crossings	11
Madej (2001)	Bridge Creek (same as Bloom, Crossings + road segments)	66
PWA (2001)	Rowdy Creek	13
PWA (2001)	Little River	12
PWA 2005d (DFG- all sites)	Road Decommissioning CDFG Fisheries Restoration Grant Program	24
PWA 2005d (DFG – Geologies present in Elk River)	Road Decommissioning CDFG Fisheries Restoration Grant Program	18
Average of all studies		**36**

Since 2000, Regional Water Board staff has sought to characterize the magnitude of restoration-related (post treatment) sediment discharges. This evaluation was necessary so that impacts from the treatment work could be documented and the overall discharge minimized over time by use of adaptive management techniques. The results of this monitoring effort in Upper Elk River are presented in Table 4.18.

82 As cited by Madej (2001).
83 As cited by Klein (2003).

Table 4.18 Treatment-related sediment discharge volumes from Upper Elk River studies.

Source	Average Post-Treatment Delivery Volume per Site (yd^3)	Number of sites monitored	Average Assessed site delivery volume (yd^3)	Percent of assessed volume delivered
BLM Headwaters Decommissioning (BLM, 2010)	15.4	26	2786.1	0.5%
GDRC WWDR 2006 Treatments (GDRC, 2007)	15.5	3	159.0	9.5%
GDRC WWDR 2007 Treatments (GDRC, 2008)	4.4	7	231.1	1.9%
Palco CAO 2006 Treatments (Palco, 2007)	4.5	25	984.9	0.5%
Palco CAO 2007 Treatments (Palco, 2008)	0.9	19	695.5	0.1%
Palco Elk Decommissioning, (PWA 2005c)	16.9	52	172.5	9.8%
Palco THP 1-97-520. (PWA 2005b)	6.5	43	NA	NA
Averages for Elk River studies	**9.1**	**53**	**838.2**	

The average sediment delivery per discharge site monitored in Upper Elk River was determined to be 9.1 yd^3. The average percent sediment delivery per site, weighted by assessed site volume was 1.1% of the assessed site volume.

PWA (2005a&b) focused on post-treatment erosion of Upper Elk River decommissioned sites. The study found that the most common and most volumetrically significant types of erosion at decommissioned stream crossings included channel incision within the excavated channel, and slumps of the excavated stream channel side slopes. Additional problems at stream crossings included over steepened fill, unexcavated fill, undercutting of slopes by excavation, natural bank adjustments, and unstable geology.

The studies cited in both Tables 4.17 and 4.18 vary in terms of the length of the time period monitored following treatment, stream power at the site, the storm history following treatment, the experience of the operators in the specific terrain, the level of site characterization, the level of operator oversight, and the budget per site. However, they offer insight into the range of potential discharges resulting from the sediment treatment work intended to restore the beneficial uses of water in Upper Elk River.

For the purposes of the Source Analysis, the average per site value from the Upper Elk River studies, 9.1 yd^3 or 1.1% of the assessed volume, was used to determine the sediment delivery to the Upper Elk River from past treatment efforts as well as anticipated future efforts. Both 9.1 yd^3 per site and 1.1% of the assessed volumes were applied to the management discharge sites treated thus far in Elk River. The average site treatment volume for site treated to date ranged from 168 to 845 yd^3.

Staff calculated the sediment delivery associated with treatment of discharge sites on HRC, GDRC, and BLM lands. Figures 4.13 and 4.14 present the resulting potential sediment delivery based upon a per-site discharge of 9.1 yd^3 or 1.1% of the assessed volume, respectively. The per-site discharge volume results in a nearly a two-fold greater overall discharge estimate than estimates based upon a percentage of the assessed site volume.

For the purposes of this sediment source analysis, staff relied upon the discharge volume per site of 9.1 yd^3 to ensure that a margin of safety was included in the estimate.

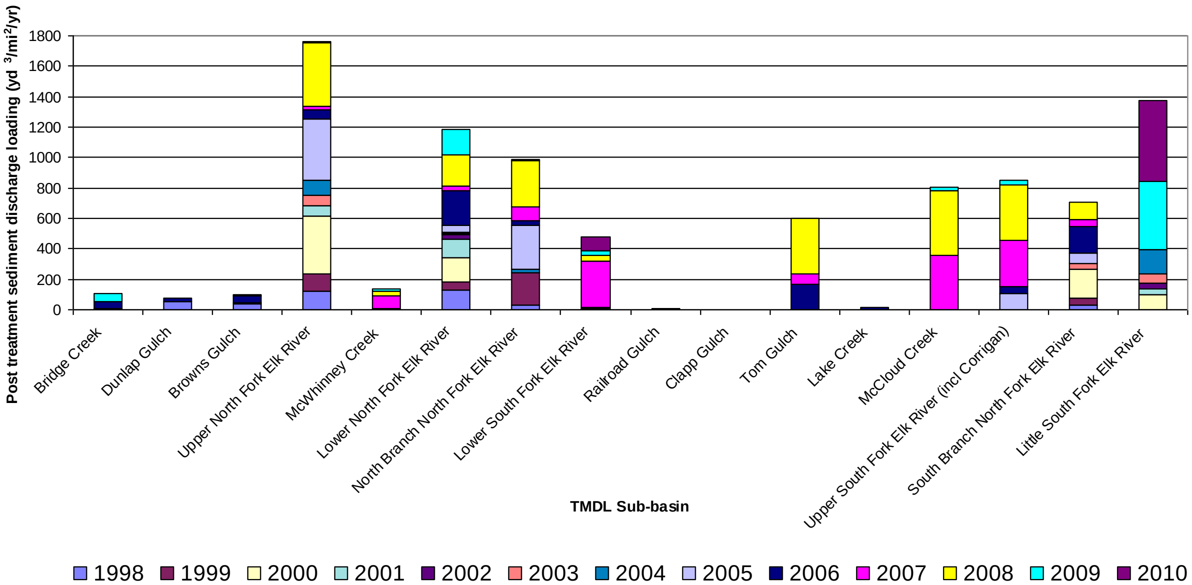

Figure 4.13 Potential sediment discharge associated with treatment of discharge sites based upon an estimated discharge of 9.1 yd^3 per site.

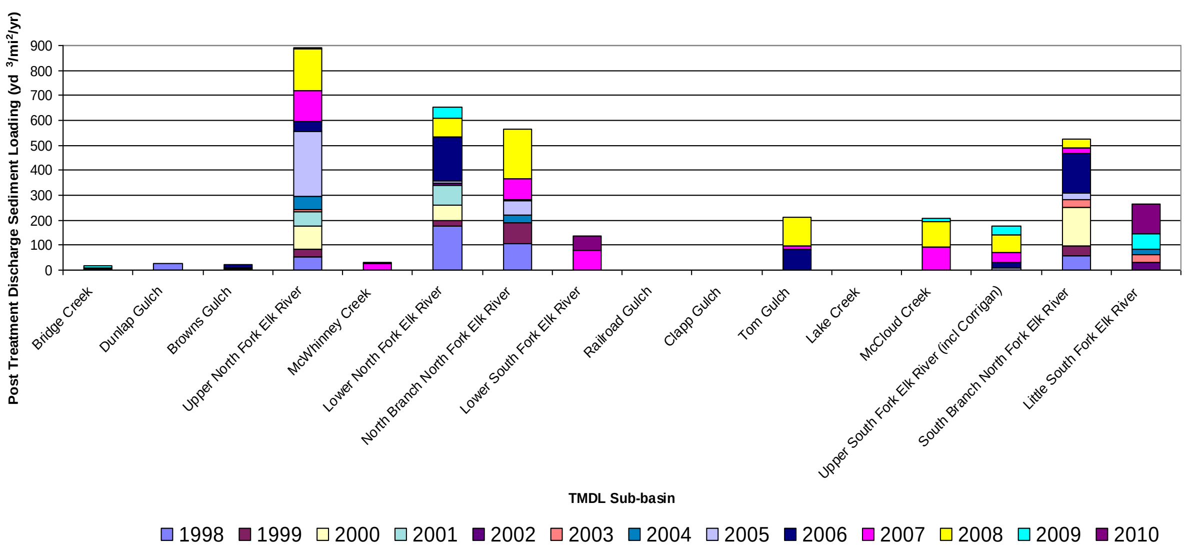

Figure 4.14 Potential sediment discharge associated with treatment of discharge sites based upon an estimated discharge of 1.1% of the assessed volume.

Table 4.19 presents the sediment loadings from management-related discharge sites to Upper Elk River as a whole.

Table 4.19 Annual sediment loading from management-related discharge sites in Upper Elk River ($yd^3/mi^2/yr$)

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Annual loading from management-related discharge sites in Upper Elk River ($yd^3/mi^2/yr$).	0	0	0	0	13	4

Uncertainties associated with post treatment discharge site analysis include:

- Sediment discharge from disturbed sites varies with runoff. If a site experiences a significant rainfall and runoff event in the first year, it is most likely that discharges will occur. However, if a site has time to stabilize prior to such an event, then discharges will be minimized. This analysis relied on a uniform discharge rate. Effectiveness of site treatments varies with project budget, available time and materials, operator expertise, and site characterization. The discharges estimated in this section represent all Upper Elk River sites synthesized.
- Refinements may be made to the loading estimates by segregating upgrade and decommission treatments.

Implications for implementation actions include:

1) Improve site characterization to include identification of features that effect treatment design and implementation. Important features include but are not limited to areas of emergent water (springs), channel gradient, stored material, geologic contacts, and location of unstable features.
2) Ensure the appropriate equipment is used for the job.
3) Stabilize the slopes, channels and headwalls with adequately sized materials.
4) Stabilize surfaces with treatments appropriate to slope angle and expected flow volume.
5) Ensure that treatments are completed far enough ahead of the rains to allow for proper attention to the site and for erosion control measures to become effective.
6) Ensure adequate monitoring to allow for early detection and treatment of problems.
7) Develop contingency plans and ensure materials are stockpiled on site to allow for emergency treatments.
8) Consider cumulative discharges associated with concentration of treatment sites in space and time.

Ground-Based Yarding-Related Sites (Skid Trails)

Sediment delivery from sites associated with ground-based yarding activities (skid trails and associated crossings) was not consistently included in the sediment source inventories conducted in Upper Elk River. Implementation of the ongoing programs will result, over time, in a more complete inventory and treatment effort for discharge sites associated with skid trails. For the purposes of this Source Analysis, Regional Water Board staff evaluated the available data on skid trails and developed past delivery estimates for use in the source inventory.

The following data sources were evaluated for estimation of sediment loading associated with skid trails; each is described in greater detail in the following sub-sections.

- Headwaters Watershed Assessment and Restoration Planning (PWA, 2000).
- HRC CAO database (HRC, 2008 update).
- Palco Freshwater Creek Skid Trail Study (Palco, 2007).
- HRC Skid Trail Surveys (HRC, 2010 update).

Headwaters Watershed Assessment and Restoration Planning

This planning project sampled and analyzed recently tractor logged areas, roads and skid trails in the Elk Head Springs area of the Upper South Fork Elk River for erosion potential and future sediment delivery. The area was selected for a reconnaissance level skid trail inventory and assessment primarily because of the recently heavily tractor logged hillslopes. The assessment was designed to identify treatable non-road erosion problems that might otherwise be missed in an inventory of road-related erosion, and to determine the relative importance of both road and non-road sources of sediment production and delivery.

The Elk Head Springs assessment area included 1.36 miles of road and a skid trail density of approximately 94 mi/mi^2. Skid trails were exposed and clearly visible on the 1994 and 1997 air photos, and were easily identified in the field. The surveyed area consisted of three haul roads, which traversed the cutover slopes. Many skid trails were constructed to access the main haul roads. The hillslopes in the assessment area were gently to moderately sloped, ranging from 0% to 50% percent in gradient, with the average slope gradient of 30%. Emergent springs are common throughout the assessment area.

The logging haul roads in the Elk Head Springs assessment area were built in the 1970's, and the upper hillslope areas were harvested around this same time. The eastern part of the assessment area was clearcut and tractor yarded in the 1980's but the majority of the assessment area was partially harvested at this time. Between 1987 and 1994, the areas which had been partially harvested previously were clearcut. The assessment area is adjacent and north of the un-entered old-growth portion of the Headwaters Forest Grove. To the north of the assessment area is the Elk Head Springs Grove, an old growth forest which was selectively harvested along its perimeter.

The assessment found that significant impacts were caused by first cycle tractor logging and the use of skid trails down broad headwall swale areas. This practice resulted in altering the natural hydrology by destroying the subsurface pipe system which resulted in reshaping surface drainage – the same effects described in Section Appendix 4C. The assessment documented swales, with no evidence of prior surface flow, collapsing inward exposing subsurface soil pipes, with flow observable at the base of the pipes from 4 to 7 feet below the grade of the swale. A series of bank failures apparently resulted in the sink holes becoming connected and creating an open channel.

The majority of the erosion and sediment delivery problems that occurred on the skid trail network, and which would not have been discovered by an inventory of the adjacent logging roads, are gullies and skid crossings. In the assessment area, a total of 27.5 miles of skid trails were identified within the 0.3 mi^2 assessment area. The skid trails included ten stream crossings, three landslides, and eight "other sites", for a total of 0.76 sites per mile of skid trail. Table 4.20 describes the volume associated with skid-trail induced gullies and Table 4.21 presents the number and volume of road-related and skid trail-related sites in the Elk Head Springs assessment area.

Table 4.20 Gully size and distribution on skid roads in the Elk Head Springs assessment area.[84]

Gully type	Gully size and distribution on skid roads in the Elk Head Springs assessment area.	Assumed average gully cross-sectional area (ft^2)	Total length of gullies (mi)	% of skid network	Approximate gully volume (yd^3)
Gullies with no sediment delivery	<1' wide and 1' deep	0.5	2.3	8.4	225
	1' wide x 1' deep to 2' wide x 2' deep	2	0.14	0.5	55
Gullies with sediment delivery	<5 yd^3 (15 sites)	2.5	0.21	0.8	103
	>5 yd^3 (6 sites)	2	0.95	3.5	372
Total			3.6	13.2	754

Table 4.21 Past and future sediment yield rates in the Elk Head Springs assessment area.[85]

Inventory Area	Total number of sites	Past Yield (yd^3)	Future Yield (yd^3)	Number of Miles	Past sediment yield rate (yd^3/mi)	Future sediment yield rates (yd^3/mi)	Density (mi/mi^2)	Past Yield (yd^3/mi^2)	Future Yield (yd^3/mi^2)
Road related sites	22	907	7427	1.66	546	4474	6	3104	25,419
Skid-related sites	21	297	1593	27.5	11	58	94	1016	5452

The total number of sites was comparable between roads and skid-trails, though the volume per unit area of erosion associated with skid trails was approximately one-fifth of the volume of erosion associated with roads. Possible explanations for these differences could include 1) many of the skids were water-barred, thus minimizing sediment delivery, 2) the skid trails are generally narrower than roads, 3) the fill-slopes associated with skids

84 Based on Table 15 in PWA (2000).
85 Based on Table 16 in PWA (2000).

are generally smaller than those associated with the wider haul roads and 4) skid trails can be constructed at steeper gradients then roads designed to accommodate a loaded log truck.

The assessment discusses the difficulty in stabilizing the sink-holes, suggesting the channels are in transition and except for removal of obvious fill, the erosion associated with the collapsing sink holes is uncontrollable (i.e. will not reasonably respond to human intervention).

Past delivery for skid-related sites was found to be 18% of the assessed future potential delivery volume.

Assessment limitations include:

- The topography and hydrology of Elk Head Springs is not characteristic of the rest of the Upper Elk River watershed. The gentle slopes and poorly incised stream channel network reduce the potential for erosion, even though there is abundant water in the area.
- The skid trail density is likely higher in the assessment area than in other parts of Upper Elk River. Lay-outs were constructed for harvesting the old-growth trees within the Elk Head Springs area more extensively than was typical of other operations in the Upper Elk River watershed.
- The volumes associated with the skid trail inventory do not include the downstream channel incision. PWA (2000) describes that the stream channel draining Elk Head Springs as "completely open and has experienced 6 feet of vertical incision. The incision in this channel has undercut the old growth trees on its banks, causing them to collapse inwards. The incision and collapse of these channels is causing substantial erosion with direct delivery. This process is irreversible, and untreatable."

HRC Cleanup and Abatement Order Database

The CAO Database contains information about a number of discharge sites, including some skid trials, though they were not consistently included in the inventory efforts.

Query of the 2008 HRC CAO Database using a simple word search of the site attributes (problem and comment fields) found that a portion of the sites were influenced by skid trails. Table 4.22 presents the frequency and volume of sites influenced by skid trails included in with the HRC CAO Database. Table 4.23 presents the findings based upon the subject subbasin.

Table 4.22 Summary of frequency and magnitude of skid trail-related discharge sites included in the HRC CAO Database.

	South Fork	North Fork	Sum
Number of sites in original CAO database	460	816	1,276
Number of sites influenced by skid trails	59	166	225
Percentage sites influenced by skid trails	13%	20%	18%?
Volume of future delivery from sites in original database	98,531	265,166	363,697
Volume of future delivery from sites influenced by skid trails	11,071	76,156	87,227
Percentage volume influenced by skid trails	11%	29%	24%?

Within the HRC CAO Database, an average of 18% of the sites were influenced by skid trails and 24% of the future sediment delivery volume was associated with sites influenced by skid trails.

Table 4.23 Summary of delivery volumes associated with sites influenced by skid trails in the CAO Database by subbasin.

Sites by subbasin	**Number sites**	**Total volume of sites (yd^3)**	**Average volume per site (yd^3)**	**Volume per unit area (yd^3/mi^2)**
Lower South Fork Elk River	6	558	93	193
Bridge Creek	2	653	327	297
Lower North Fork Elk River	5	1,669	334	333
Upper South Fork Elk River (Including Corrigan Creek)	23	3,692	161	455
Browns Gulch	4	489	122	551
Lake Creek	5	1,710	342	805
McWhinney Creek	3	1,152	384	904
Tom Gulch	30	6,821	227	2,718
Dunlap Gulch	3	2,019	673	3,076
Upper North Fork Elk River	63	23,784	378	5,451
North Branch North Fork Elk River	57	27,186	477	6,770
South Branch North Fork Elk River	24	17,494	729	9,062
sum/average	**225**	**87,227**	**354**	**2,551**

The CAO inventories were not focused on identifying skid trail-related sites and thus the results do not represent a complete inventory of skid trail sites.

Freshwater Creek Skid Trail Study

Because the CAO inventories did not originally target skid trail-related sources, PALCO conducted a skid trail specific study (PALCO 2007[86]) to determine the relative magnitude of skid trail related sources. This study also evaluated the extent to which the sites may

86 Palco, March 14, 2007. Skid Trail Sediment Source Assessment Project, Freshwater Creek, Freshwater Creek CAO R1-2006-0046, Project Report.

have been identified in the previous inventories. The Freshwater Creek study (Skid Trail Study) was conducted in two units in areas predominated by the Wildcat and Yager formations.

The two units were selected based on the extent of tractor yarding conducted on the units. Units exhibiting a high intensity of ground-based yarding were selected to help define the extent to which a lack of skid trail specific data influences a sediment budget. The units were selected to be representative of the watershed. Field inventories were conducted using LIDAR-based topographic maps to focus on watercourse areas, where a higher potential for sediment delivery exists.

Table 4.24 presents the frequency and volume of sites influenced by skid trails as identified in the Skid Trail Study.

Table 4.24 Sediment delivery associated with skid trails in the Freshwater Creek Skid Trail Study

Characteristic	Parameter	School Forest Unit 1	Cloney Gulch Unit 2
Area of survey unit	mi^2	0.25	0.24
Total number of skid trail sources	Count in unit	36	36
	Percent identified in previous Inventory	36%	25%
Frequency	Number / mi^2	147	147
Volume delivered	Total volume from unit (yd^3)	2,810	2,365
	Average volume per site (yd^3)	78	66
	Annual delivery volume from unit (yd^3/yr)	120	118
	Annual volume per unit area ($yd^3/mi^2/yr$)	480	492
	Average annual volume per source (yd^3/yr)	3.3	3.3

Within the units inventoried under this effort, 64-75% of the skid trail sites were missed by the previous inventories. The average site volume tended to be smaller than those identified in Table 4.24, perhaps indicative of the more thorough investigation.

The study also investigated the feasibility of treating identified sites. The authors found that 33-50% of the sites were feasible to treat, for an annual sediment discharge reduction of 35-55 yd^3/yr.

No such study was conducted in the Elk River watershed. The timing and techniques of the tractor logging in the surveyed areas may not be representative of conditions in Elk River.

<u>Palco/Humboldt Redwood Company Skid Trail Surveys</u>

Pursuant to CAO requirements, Palco, and subsequently HRC, conducted surveys of skid trails in both Freshwater Creek and Elk River. According to a 2010 CAO update (HRC, 2010), 1,337 sites were found with an average future delivery of 159 yd^3. According to those data, the estimated past delivery is 53% of future delivery, resulting in an average past delivery of 84 yd^3.

Estimates of Skid Trail Sediment Loading

For the purposes of the sediment source analysis, the following elements are relied upon from the sources of data described above:

- The HRC CAO Database indicates an average of 6.1 sites/mi^2.
- Based upon the Palco Freshwater Creek Skid Trail study, Regional Water Board staff assumed the HRC CAO inventory missed 70% of the skid trail sites, indicating an additional 10.4 sites/mi^2 (6.1 sites/mi^2 x 1.7).
- The average future sediment delivery volume of sites not included in the HRC CAO Database are based upon the average of the Palco Freshwater Creek Skid Trail study units (64 yd^3 and 78 yd^3) and the Elk Head Springs inventory (76 yd^3), resulting in an average assessed future delivery volume of 73 yd^3.
- Past delivery is based upon the Elk Head Spring inventory in which the past volume was estimated to be 18% of the assessed future delivery volume.
- For lack of a comprehensive skid trail construction history, Regional Water Board staff assumed the past sediment delivery occurred at similar rates of discharge as the past delivery from all other management-related discharge sites: 9% of total 1954-1967; 21% of total 1967-1974; 29% of total 1975-1987; 26% of total 1988-1997; and 16% of total 1998-2000.
- Assume future delivery will occur uniformly over the next 50 years (time period associated with a low treatment priority schedule).

Figure 4.15 presents the results from skid-trail related past sediment delivery for the subbasins in the Upper Elk River.

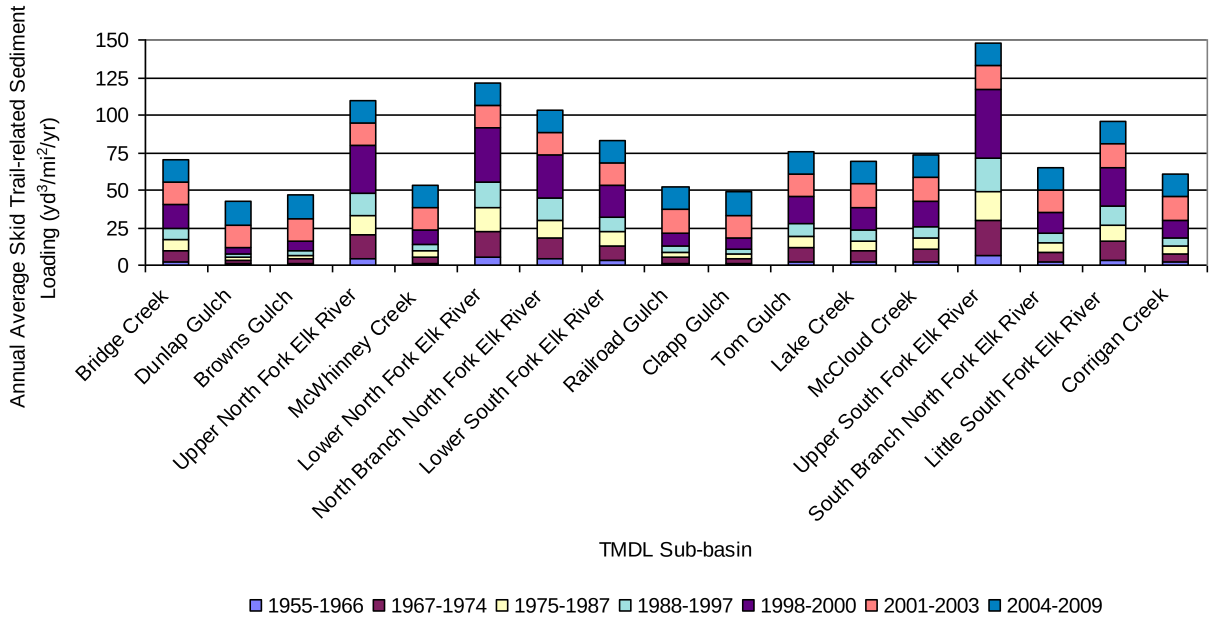

Figure 4.15 Annual average past sediment loading from skid trail-related sources by subject subbasins.

Table 4.25 presents the sediment loadings from skid trail sites to Upper Elk River as a whole.

Table 4.25 Annual sediment loading from skid trail sites in Upper Elk River ($yd^3/mi^2/yr$)

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Annual loading from skid trail sites in Upper Elk River ($yd^3/mi^2/yr$).	4	12	11	12	26	15

Uncertainties associated with the skid trails analysis include:

- No skid trail study was conducted for Upper Elk River. The timing and techniques of the tractor logging in the Freshwater Creek surveyed areas may not be representative of conditions in Elk River.
- The CAO inventories were not focused on identifying skid trail-related sites and thus the results do not represent a complete inventory of skid trail sites.
- For lack of a skid trail construction history, Regional Water Board staff assumed the past sediment delivery occurred at similar rates of discharge as the past delivery from all other discharge sites on HRC lands.
- Regional Water Board staff assumed future delivery will occur uniformly over the next 50 years, consistent with a low treatment priority. Some skid trail sites may erode more rapidly.
- The topography and hydrology of Elk Head Springs is not characteristic of the rest of the Elk River watershed. The gentle slopes and poorly incised stream channel network reduce the potential for erosion, even though there is abundant water in

the area. Other steeper areas of the watershed may result in greater erosion potential.
- The skid trail density is likely higher in the assessment area than in other parts of Elk River since tractors were used to construct lay-outs for harvesting the old-growth trees with the Elk Head Springs area.
- The volumes associated with the skid trail inventory do not include the downstream channel incision.

Implications for implementation actions include:
1) Skid trail features should consistently be included in future inventories.
2) Avoid creation of new discharge sites from skid-related features by use of alterative yarding systems, as appropriate.
3) Treat skid trail-related collapse of soil pipes (i.e. sink hole erosion) as part of sediment control programs.
4) Develop and implement a strategy to treat skid trail-related erosion in areas inaccessible to heavy equipment.

Road Surface Erosion

Road surface erosion represents the sediment transport and delivery from the road surfaces within the watershed. The material eroded from road surfaces is relatively fine grained in size and discharge can occur during each rain event (a press event), rather than discharging episodically (pulse event), such as occurs in discharge associated with landslide features. For this reason road surface erosion has a chronic effect on water quality.

Factors affecting sediment discharge from road surfaces include:
- Rainfall intensity, frequency and timing;
- Soil and geologic properties;
- Road location on the landscape (e.g. near stream, mid-slope, ridge top);
- Hillslope and road gradients;
- Road construction techniques (e.g. insloped or outsloped road prism; characteristics and number of stream crossings);
- Surfacing (e.g. native surface, rock);
- Seasons of use (year-around versus summer);
- Usage (e.g. all-terrain vehicles, pickup truck, loaded log trucks).

While road density is not a direct measure of road surface erosion delivery, the higher the density, the higher the potential for surface erosion delivery. Staff reviewed the Elk River WA (Palco, 2004) and Palco ROWD (2005) for road construction history and resulting road densities in Elk River. The four information sources presented in the WA include:
- Road construction history for North Fork Elk River 1954-2000 (CWE Table 9).
- Road densities by subbasin for Elk River area as of 2002 (Table B-10).

- Road segment data used in the Palco WA SEDMODL2 runs to evaluate road-related surface erosion (ERSC Road Surface Erosion.xls).
- Road miles and associated sediment loading by different surface categories in North Fork and South Fork Elk River as of 2004 (Palco ROWD).

Figure 4.16 illustrates road density over time, based on the history of road construction in the North Fork Elk River.

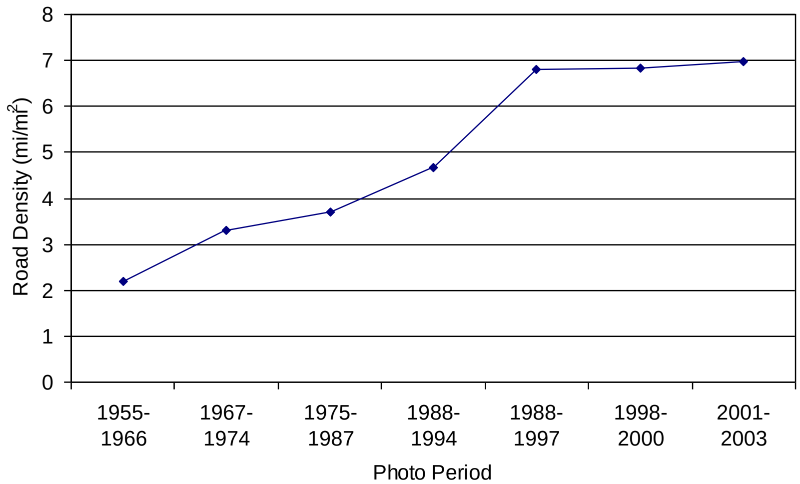

Figure 4.16 Road construction history in North Fork Elk River (based on Palco WA).

Staff estimated the change in road densities for the remainder of the subject subbasins based on the rate of road density increase demonstrated in North Fork. The resulting road densities over the TMDL analysis time periods in the subject subbasins are presented in Figure 4.17.

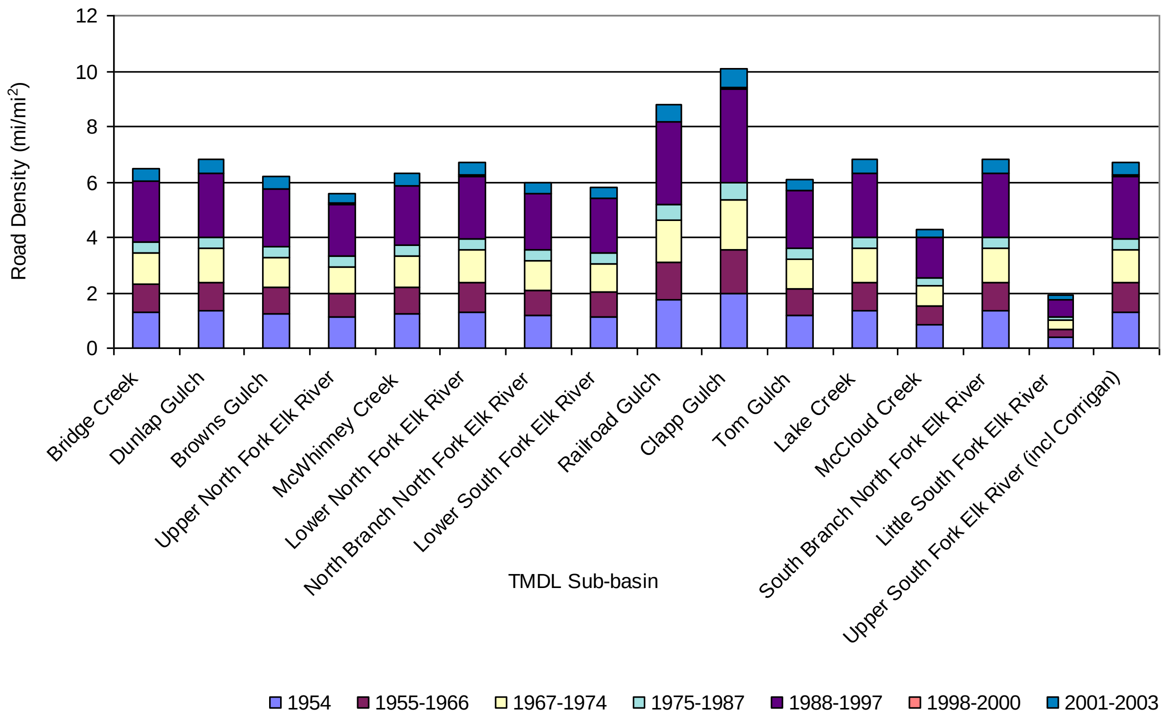

Figure 4.17 Estimated road densities in TMDL subbasins.

The Palco ROWD[87] presents road categories, associated lengths and sediment delivery estimates for North Fork and South Fork Elk River (HRC lands only) based upon 2004 conditions. This information is summarized in Table 4.26.

Table 4.26 Road category, associated length, and estimated sediment loading based upon Palco ROWD (2005).

		North Fork (HRC Lands only)		South Fork (HRC Lands only)	
Road category	Unit sediment delivery (yd³/mi/yr) (Palco, 2004)	Density (mi/mi²)	Loading (yd³/mi²/yr)	Density (mi/mi²)	Loading (yd³/mi²/yr)
General use – Rocked Stormproofed	7.3	1.55	11.3	0.55	4.0
RS – THP	16.6	0.69	11.4	0.64	10.6
RS- Idle	4.2	0.30	1.3	0.26	1.1
Paved	3.6	0.15	0.5	0.07	0.2
Dirt Stormproofed	19.1	0.58	11.1	0.52	9.9
Rocked	7.0	0.30	2.1	0.25	1.8
Dirt	24.4	1.18	28.8	1.06	25.8
Abandoned	3.2	1.87	6.0	8.44	27.0
Total		**6.63**	**72.5**	**11.78**	**80.4**

87 Palco ROWD (Palco, 2004), Appendix D General road surface sediment delivery estimates for Elk River using DNR.

Regional Water Board staff estimated the proportion of roads in each of the different road categories as presented in Table 4.26 and applied those proportions to the subbasins in North Fork and South Fork, as representing 2001-2003 conditions. Staff assumed that the road densities in the Clapp Gulch and Railroad Gulch subbasins were proportional to the South Fork densities. Staff applied the unit sediment delivery from Table 4.26 to the 2001-2003 conditions. To estimate 1998-2000 conditions, staff assumed: 1) the 2001 to 2003 time period provided the best estimate for determining the proportion of rocked roads within the subbasins; and 2) roads were not "stormproofed." For the period 1955-1997, Regional Water Board staff assumed roads were unrocked and of native material (dirt).

Figure 4.18 presents the resulting sediment loading estimates from road surface erosion over time for the TMDL subbasins.

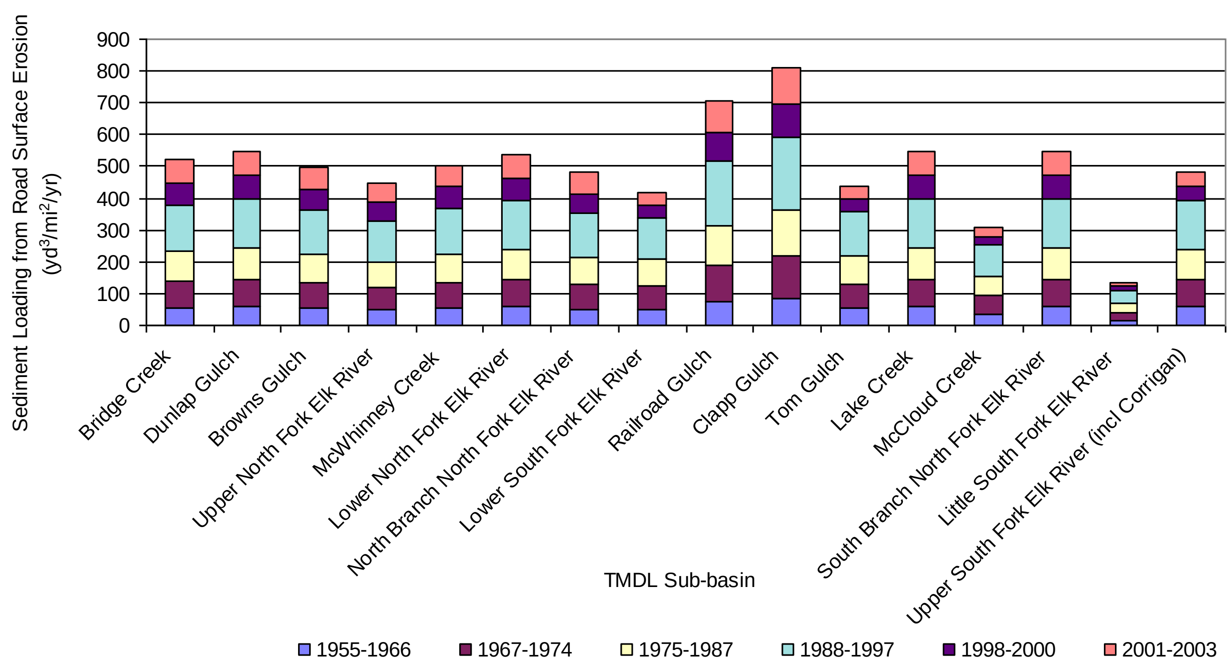

Figure 4.18 Sediment loading associated with road surface erosion for TMDL subbasins.

The annual loading delivered over time to Upper Elk River from road surface erosion is summarized in Table 4.27.

Table 4.27 Annual sediment loading from road surface erosion in Upper Elk River ($yd^3/mi^2/yr$)

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Annual loading from road surface erosion in Upper Elk River ($yd^3/mi^2/yr$).	52	78	87	137	55	56

Uncertainties associated with the road surface erosion analysis include:

- WA presents information regarding the sensitivity of parameters associated with SEDMODL. The results of the sensitivity analysis concluded that the frequency of road use has a significant effect on the production of sediment from road surfaces. If the traffic factor is not representative of actual conditions, the resulting loadings estimates will be significantly affected.

- Regional Water Board staff did not conduct the SEDMODL runs but rather evaluated the data files and results of the SEDMODL runs associated with the Palco WA and the estimate provided in the Palco ROWD.
- Lack of comprehensive road construction history for TMDL subbasins limit the confidence in the results.

Implications for implementation actions include:

1) Road surface material greatly influences the sediment discharge associated with roads. Rock surfacing can minimize rills and chronic discharges, especially if the road has any gradient. Road sections draining to watercourses should be treated up to the hydrologic divide.
2) Ensure road surface can support intended use. Avoid use of roads with vehicles that can cause erosion. This includes quads and light trucks on dirt roads and may include loaded trucks on rocked roads.
3) Reduce existing road densities. Avoid new road construction, unless offset by replacing poorly located roads. Decommission unneeded roads.
4) Stabilize the surface of abandoned roads by applying mulch, planting trees, etc.
5) Ensure road drainage is prevented from direct delivery to watercourses (hydrologically disconnected).

Management-Related Harvest Surface Erosion

Management-induced vegetation and ground disturbance can influence the magnitude of surface erosion. Timber harvest activities can affect this source category by:

1) Removal of overstory canopy cover which increases the effective rainfall that reaches the ground to dislodge and transport soil particles;
2) Soil compaction through the use of heavy equipment, skidding trails of logs, and site preparation altering surface and subsurface flow paths and concentrating and diverting water;
3) Disturbance of the understory vegetation, top soil, and mycology network, all which have the ability to affect the natural binding properties of soil ;
4) Harvesting trees thereby reducing the future recruitment of duff which naturally protects the forest soils from disturbance and erosion;
5) Utilizing mechanical site preparation techniques for harvesting which disturbs and/or removes duff and reduces future soil protection.
6) The use of burning which reduces cation exchange capacity and long-term productivity of soil and exposes soil to erosion, and
7) The use of herbicides which bind with soil particles increasing erosion.

The style and location of timber harvest operations affect surface erosion. Generally speaking, the magnitude of management-related surface erosion is a function of slope, ground disturbance and canopy removal.

Staff relied upon the sediment loading estimates for in-unit harvest surface erosion as developed by Palco (2004) in the Watershed Analysis. They applied Water and Erosion Prediction Program (WEPP)[88] and estimated sediment delivery of 0.8 tons/acre using clearcut methods (tractor or cable) and 0.5 tons/acre for partial cut methods (tractor or cable). While it is acknowledged that sediment delivery from surface erosion continues for several years following harvest, for the purpose of this Source Analysis, staff assumed that delivery occurred the year of harvest.

Staff relied on harvest history data from CDF for the 1988-2010 time period (as described in Appendix 4B) and data presented in the Palco WA[89] for the earlier time periods. Staff assumed the same proportion of harvesting in North Fork occurred in the rest of the watershed.

Watershed harvest history included: acres harvested and silvicultural method employed. This parameter is calculated simply as the "clearcut equivalent acres" harvested during a particular time period. The harvest acres were converted to clearcut equivalents by applying a weighting coefficient that reflects the proportion of canopy removed for the listed silvicultural method (Table 4.28). The coefficients were based upon the best professional judgment of staff at Redwood Science Lab, Cal Fire and Regional Water Board.

Table 4.28 Canopy removal coefficients used to calculate clearcut-equivalent acreages from harvest history.

Silvicultural Method	Canopy Removal Coefficient
Clearcut Road Conversion Rehabilitation	1
Shelterwood Removal Cut Seedtree Removal Cut Seedtree Step Cut Shelterwood Prep Step Variable Retention	0.75
Selection Commercial Thin Transition Alternative Prescription	0.5

Staff assumed that harvest prior to 1988 was represented by a canopy removal coefficient of 0.75.

88 WEPP was developed by Bill Elliot.
89 CWE Table 9 – Harvest and road building history on Palco-owned land.

Figure 4.19 presents the resulting clearcut equivalent acres data for each subject subbasins. Using this data, staff estimated total sediment loading resulting from harvest-related surface erosion for each of the subbasins (Figure 4.20).

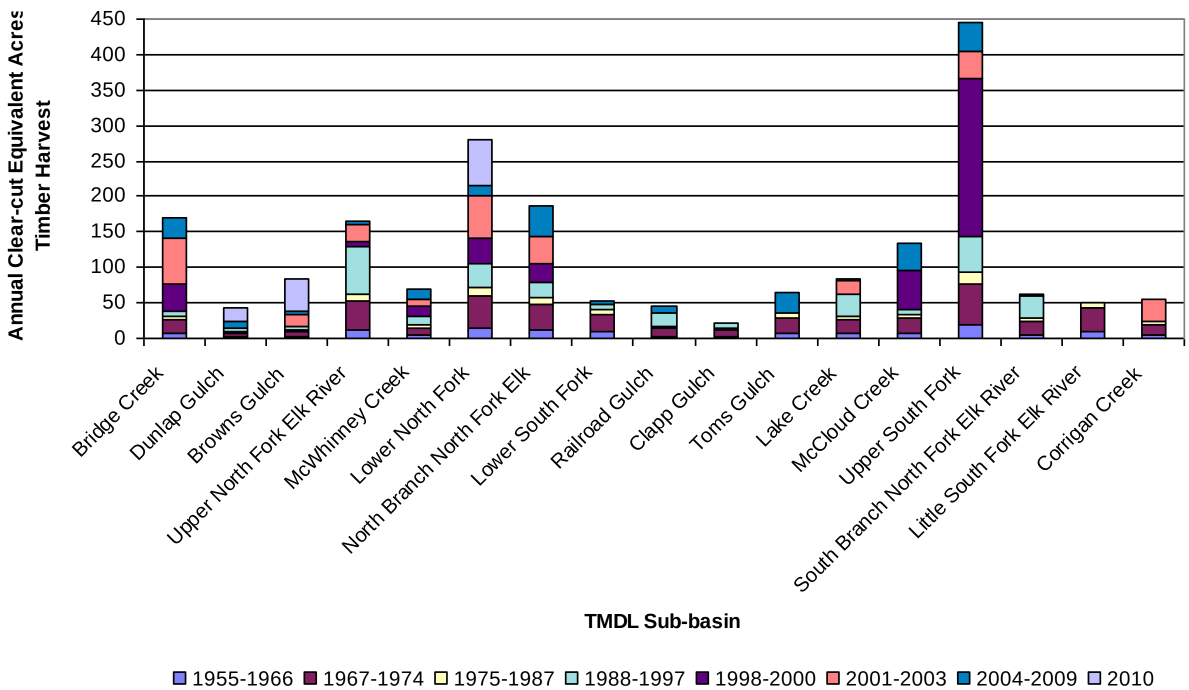

Figure 4.19 The annual clear-cut equivalent harvest acres for TMDL subbasins over analysis time periods.

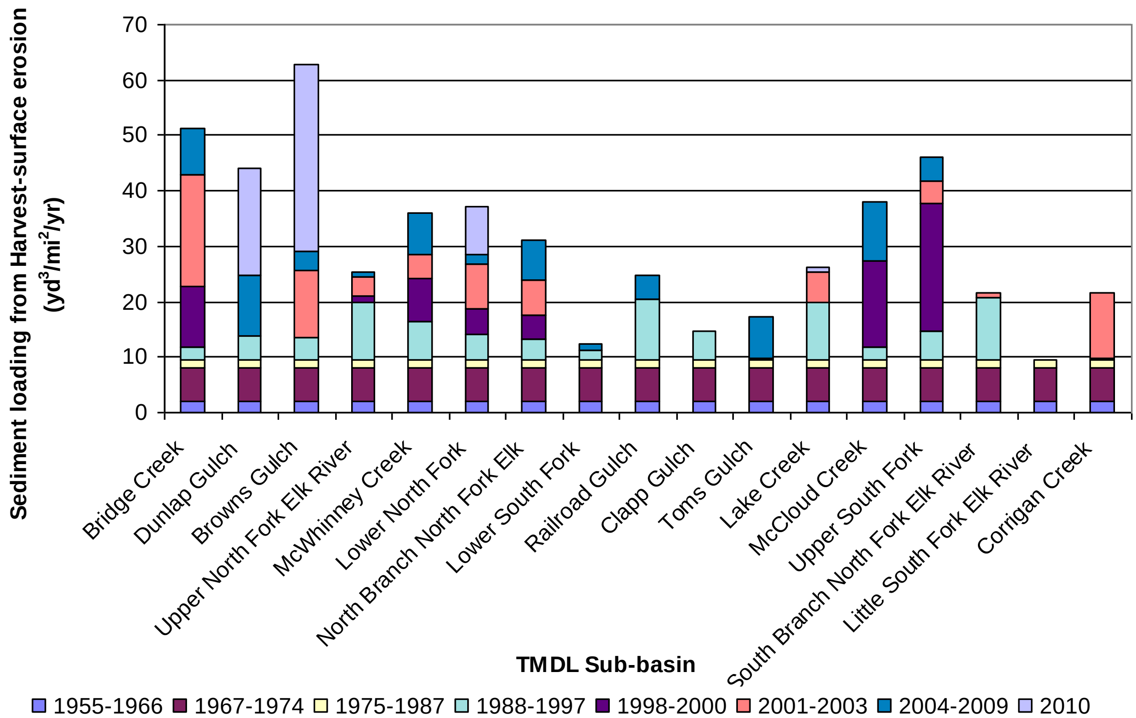

Figure 4.20 Sediment loading to TMDL subbasins from harvest-related surface erosion over analysis time periods.

Table 4.29 presents the sediment loadings from harvest surface erosion to Upper Elk River as a whole.

Table 4.29 Annual sediment loading from harvest surface erosion in Upper Elk River ($yd^3/mi^2/yr$)

Time Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003
Annual loading from harvest surface erosion in Upper Elk River ($yd^3/mi^2/yr$).	2	6	2	5	6	5

Uncertainties associated with harvest surface erosion analysis include:

- The surface erosion sediment delivery estimates are based upon values reported in the Palco Elk River Watershed Analysis, as estimated from their applications of the WEPP model. Staff did not independently apply the WEPP model to this source catagory.
- Discharge of sediment following harvest likely follows an exponential decay for a period of years until ground cover is regained through growth of understory vegetation and re-accumulation of duff material. For simplicity sake, and for this Source Analysis only, staff assumed the discharge occurred in the first year of harvest.
- The harvest history prior to 1988 is uncertain due to lack of a comprehensive harvest history for the Elk River watershed.

- The appropriate use and effectiveness of the WEPP is unproven in the Upper Elk River at this time.
- Palco WA (2004) indicates that no direct measurements of surface erosion rates were made in the Elk River watershed during the watershed analysis, but incidental observations of the evidence of surface erosion were made during field survey investigations for the Freshwater Creek Watershed Analysis.
- The WEPP model documentation states that the accuracy of predicted erosion rates is, at best, ±50 percent (Palco, 2004 citing Elliot et al. 2000).
  The Palco WA (2004) discusses other estimates of harvest surface erosion sediment delivery, including:1) a study in Redwood Creek, 2-7 tons/acre/yr for cable and 2-30 tons/acre/yr for tractor yarded slopes and 2)observations in Freshwater Creek indicating at least 5 tons/ac/yr for the first year following a cable yarded and burned unit and 4-6 tons/ac/yr from skid trails for the first three years following harvest.
- Based upon these other estimates, the WEPP estimates may underestimate harvest surface erosion by 2.5 to 37 times.

Implications for implementation actions to control loading from harvest surface erosion include:

1) Minimize the extent of disturbed land through the rate and scale of land disturbance.
2) Minimize ground disturbance through selection of management measures including harvest and yarding techniques.
3) Minimize hydrologic modification due to canopy removal, compaction, and site treatment.
4) Minimize disturbance of steeper slopes
5) Maintain duff-producing trees capable of post-harvest leaf drop to ensure maintenance of an adequate duff layer.
6) Implement surface erosion control measures on areas of disturbed and unvegetated soil, including skid trails. Consider the use of portable chippers.
7) Recover healthy soil and reduce soil mobility through use of mulch, compost tea, and mycelium.

4.5 Management-Related Sediment Loading (2004 to 2011)

This section presents a summary of the loading associated with management-related sources for the 2004-2011 time period.

In 2013, as part the watershed analysis revisit required by their HCP, HRC developed a sediment budget for the 2001-2011 time period (HRC, 2013). It provides another line of evidence, coupled with the estimates of sediment loading up through the 2003 time period which are analyzed in Section 4.4. Because the analysis methods used by HRC vary from those employed by staff to assess the 1955-2003 time period, some modification of the estimates were warranted to allow for temporal comparison of sediment sources as well as to reflect findings related to natural loading. Table 4.30 provides a comparison of the source categories and the associated loading for Upper Elk River based upon the TMDL Source Analysis estimates and the HRC WA sediment budget estimates for the 2001-2003 and 2001-2011 time periods, respectively.

Table 4.30 Comparison of TMDL sediment loading and HRC Elk River Watershed Analysis sediment loading (HRC, 2013).

<table>
<tr><td></td><td></td><td>TMDL 2001-2003</td><td>HRC WA 2001-2011</td></tr>
<tr><td></td><td>TMDL Source Category</td><td>$yd^3/mi^2/yr$</td><td>$yd^3/mi^2/yr$</td></tr>
<tr><td rowspan="6">Natural</td><td>Soil Creep</td><td>0</td><td>57</td></tr>
<tr><td>Bank Erosion</td><td>9</td><td rowspan="2">130</td></tr>
<tr><td>Small Streambank Landslides</td><td>26</td></tr>
<tr><td>Shallow Hillslope Landslides</td><td>30</td><td>4</td></tr>
<tr><td>Deep Seated Landslides</td><td>3</td><td>1</td></tr>
<tr><td>Total Natural Loading</td><td>68</td><td>193</td></tr>
<tr><td rowspan="11">Management-Related</td><td>Low Order Channel Scour</td><td>12</td><td rowspan="3">50</td></tr>
<tr><td>Management-Related Bank Erosion</td><td>55</td></tr>
<tr><td>Management-related Streamside Landslides</td><td>294</td></tr>
<tr><td>Management-related Open Slope shallow landslides</td><td>51</td><td>15</td></tr>
<tr><td>Road-related Landslides</td><td>20</td><td>42</td></tr>
<tr><td>Controllable sediment discharge sites</td><td>39</td><td>36</td></tr>
<tr><td>Skid Trails</td><td>15</td><td>13</td></tr>
<tr><td>Treatment of Controllable Sediment Discharge Sites</td><td>4</td><td>5</td></tr>
<tr><td>Road surface erosion</td><td>56</td><td>20</td></tr>
<tr><td>Harvest surface erosion</td><td>5</td><td>5</td></tr>
<tr><td>Total management-related Loading</td><td>552</td><td>185</td></tr>
<tr><td rowspan="2">Total</td><td>Total Loading</td><td>620</td><td>377</td></tr>
<tr><td>Percent of Natural Loading</td><td>907%</td><td>196%</td></tr>
</table>

As explained below, the HRC WA loading estimates help to corroborate the TMDL estimates from in-channel sources (soil creep, bank erosion, streamside landslides, and headward channel incision), provide improved estimates of road surface erosion, and demonstrate reduced loading from landslides. However, staff finds that the methods used in Section 4.3 of this Sediment Source Analysis provide more reliable estimates of natural sources because they were developed based upon direct observations of conditions in a reference subbasin in the Upper Elk River watershed.

The total loading estimates developed in this Sediment Source Analysis for the 2001-2003 time period and the HRC WA estimates for the 2001-2011 estimates are 620 $yd^3/mi^2/yr$ and 377 $yd^3/mi^2/yr$, respectively. Some portion of the variation in these total loading estimates likely results from differences in survey and data analysis methods and some portion likely demonstrate reductions in sediment loading and differences in storm magnitude during the analyses time periods. Following is a discussion of analyses methods that likely influence the loading estimate differences between the Source Analysis and the HRC WA, and staff's evaluation of how to most reliably and comparably estimate the 2004-2011 time period.

First, this Source Analysis relies on surveys conducted in the reference subbasin, Upper Little South Fork Elk River, ensuring that the estimates are uninfluenced by persisting effects of management history. This is especially important in the Wildcat Group in which soil pipes are prevalent and management-related modifications to hydrology has resulted in wide-spread evidence of their collapse (Appendix 4C). Much of the managed portions of Upper Elk River contain incised watercourses with ongoing erosion of the banks and adjacent slopes. Because it can be very difficult to identify the management-related factors contributing to the in-channel source category loading estimates based upon field indicators alone, staff used a comparative analysis from managed and unmanaged areas to develop loading estimates for these sources.

Second, the estimate of the soil creep rate used in the HRC WA is much larger than that identified as the most appropriate for use in Upper Elk River, as identified by Buffleben (2009) and described in Section 4.3. Soil creep is a difficult process to evaluate and generally has low expected accuracy. There is no way to verify the most appropriate estimate of soil creep, as all available estimates in the literature are based upon studies in other locations and may not be valid in Upper Elk River, especially given differences in geology and seismic activities. However, the material moved down slope via soil creep is delivered to the stream channel through bank erosion and streamside landslides. Accounting for soil creep, bank erosion, and streamside landslides together double counts the movement of material from the hillslope to the stream channel. Soil creep estimates are useful when there is not reliable data for bank erosion and streamside landslides. To avoid double counting, either bank erosion or creep estimates are generally relied upon, or creep is subtracted from the bank erosion estimates. Estimates of creep rates were included in the WA in addition to the bank erosion estimates. For these reasons, staff believes it most appropriate to rely on survey results for bank erosion and streamside landslides and not include the added loading from soil creep.

As described in Appendix 4C, staff developed current drainage density estimates for reference and managed areas in Upper Elk River and applied the drainage densities uniformly across the landscape to inform sediment loading associated with bank erosion and streamside landsliding. The HRC WA also developed estimates of drainage density by subbasin based upon THP mapping efforts (Appendix 4C, Figure 1) resulting in an average drainage density estimate of 9.96 mi/mi^2 on their ownership in Upper Elk River. The HRC WA drainage density estimates may offer under-estimates of current drainage network due to:

1) Incomplete mapping of low order channels in the watershed assessment area as they were done associated with THP lay-out over time and standards of practice for identification of low order watercourses have evolved.
2) Most watercourses were initially mapped on the coarser-scale USGS topographic maps. The use of LiDAR for channel mapping would likely improve the channel mapping, however was not available until 2005.
3) Watercourses have likely extended following first, second, and third cycle logging. Watercourses identified as part of THP layout in the period spanning the1980s through the 2000s, likely have incised headward following THP operation.

Additionally, the channel surveys described in Appendix 4C were conducted in the Wildcat Formation and may over-estimate the drainage density in terrain dominated by less erodible Franciscan and Yager formations. In the Source Analysis estimates for 1955-2003, staff relied upon the estimates in Appendix 4C; for the purposes of comparing across analysis time periods, staff finds that reliance on those estimates for the 2004-2011 time period is appropriate.

The total natural and management-related estimates from in-channel sources are 397 yd^3/mi^2/yr and 180 yd^3/mi^2/yr, for the Source Analysis 2001-2003 estimates and the HRC WA 2001-2011 estimates, respectively. This constitutes 64% and 48% of the total loading estimates from each of the analyses. However, both estimates indicate that close to half of the overall loading is attributed to in-channel sources. The HRC WA estimates corroborate the TMDL Source Analysis finding that in-channel sources persist as a significant portion of the contemporary sediment loading. The HRC WA however, attributes the majority (79%) of the in-channel sources to natural loading, whereas the Source Analysis estimates for 2001-2003 indicates 9% is attributable to natural loading. Staff find that the estimates of natural loading from in-channel sources as described in Section 4.3 provide the best available estimates because of reliance on a reference subbasin without persisting management effects.

The HRC WA data indicate a continuing decline in landsliding rates as compared to an all-time high in the 1988-1997 time period, and a reduction in open-slope shallow landsliding since 2001-2003 time period. However, there has not been a storm of an intensity which is expected to result in widespread landsliding (>3”/24 hours) since 2003.

The HRC WA estimates that the majority of the open-slope landslides now present were initiated from areas harvested prior to implementation of the HCP in 1999. Of the road-related landslides identified in the WA sediment budget, the majority of the sediment was delivered from non-stormproofed abandoned roads, followed by non-stormproofed haul roads. This category of road has shrunk as Palco and HRC have implemented road stormproofing programs in accordance with the HCP.

With respect to sediment loading estimates from management discharge sites, staff identified a significant discrepancy in the estimates associated with past and future erosion, with the future erosion estimates resulting in much greater sediment loading. While the evaluation of future erosion provides important information to inform site treatment priorities, staff determined that it did not provide a reliable estimator of sediment loading because the discharge rate from a site is not uniform. The HRC WA also noted this discrepancy and thus relied upon loading estimates based upon past discharge estimates, with consideration to treatments conducted in the intervening years.

HRC conducted effectiveness monitoring to evaluate the sediment loading associated with road surface erosion (Sullivan et al. 2011). They found that, during the period they monitored, sediment loading associated with stormproofed surfaced roads with use limitation during wet weather were lower than previously estimated. The study did not evaluate sediment loading associated with native surfaced non-stormproofed roads. For the purposes of estimating sediment loading from stormproofed, surfaced roads, the HRC WA estimates appear to be the best available information and staff find them appropriate to rely upon; for native surfaced roads, staff finds that the loading described in Section 4.4 remains the best available information.

The HRC WA sediment budget separates pre-HCP versus HCP-related management sources, reflecting a reduction in sediment loading associated with more recent management activities as compared to management-activities from 1999 and earlier. These distinctions are useful to inform watershed implementation actions. However, for the purposes of the TMDL Source Analysis, only a distinction between natural and management loading is required, not the influence on sediment loading of contemporary practices versus the persisting effects of past management.

Staff find the compilation of data contained in the HRC WA sediment budget provides useful information relative to the 2004-2011 time period and makes use of it in this Source Analysis, as appropriate. However, to allow comparison across time periods, some modifications are needed. These include:

- Removal of soil creep estimates (to avoid double counting);
- Use of the Upper Little South Fork Elk River data to estimate natural bank erosion and natural streamside landslide rates;
- Reliance on the loading estimates based upon surveys conducted in Upper Elk River Study Subbasins for management-related bank erosion loading;
- Reliance on the HRC WA streamside landslide and bank erosion results for total loading associated with in-channel sources by subbasin;
- Estimate of management-related streamside landslides as the HRC WA unit totals (sediment volume per stream mile)of in-channel sources, adjusted for current draiange density estimates from this Source Analysis, minus the Source Analysis

estimates of loading for natural bank erosion, natural streamside landslides, managemnt bank erosion, and low-oder channel incision. In equation form that is expressed as:

Management Related Streamside Landslides = Total In-Channel Sources – ∑(Natural Bank Erosion, Natural Streamside Landslides, Low-Order Channel Incision)

- Extrapolation of past discharge estimates from management-related discharge sites to the 2004-2011 time period.

4.6 Summary of Management-Related Sediment Loading (1955 to 2011)

Appendix 4H provides a summary of the management-related loading by source category and photo period for each of the subbasins in Upper Elk River.

Table 4.31 and Figure 4.21 present the total loading by source category per analysis time period, as well as the natural and management -related sediment loading. The Upper Elk River loading values were calculated as the area-weighted averages from the subbasins. The 1988-1997 time period represents the greatest loading over the analysis periods, 1,134 $yd^3/mi^2/yr$ or 1659% over naturally occurring background. Table 4.32 presents the total loading in terms of $tons/mi^2/yr$.

Table 4.31 Summary of Upper Elk River volumetric loading ($yd^3/mi^2/yr$) by sediment source category for analysis time periods.

		Sediment Loading ($yd^3/mi^2/yr$)						
	Source Category	**1955-1966**	**1967-1974**	**1975-1987**	**1988-1997**	**1998-2000**	**2001-2003**	**2004-2011**
Management	Low Order Channel Scour	67	23	14	21	32	12	14
	Bank Erosion	43	46	49	52	54	54	57
	Streamside Landslides	227	159	30	265	294	294	217
	Open Slope Shallow landslides	189	82	6	201	118	51	5
	Road-related Landslides	99	29	15	307	3	20	25
	Management discharge sites	30	60	80	65	39	39	39
	Skid Trails	4	12	11	12	26	15	15
	Treatment of Management Discharge Sites	0	0	0	0	13	4	24
	Road Surface Erosion	52	78	87	137	55	56	17
	Harvest Surface Erosion	2	6	2	5	6	5	4
	Total management-related Loading	**713**	**495**	**292**	**1,065**	**639**	**551**	**417**
Natural	Bank Erosion	9	9	9	9	9	9	9
	Small Streambank Landslides	26	26	26	26	26	26	26
	Shallow Hillslope Landslides	30	30	30	30	30	30	30
	Deep seated Landslides	3	3	3	3	3	3	3
	Total Natural Loading	**68**	**68**	**68**	**68**	**68**	**68**	**68**
	Total Loading	**781**	**563**	**360**	**1,133**	**707**	**619**	**485**
	Percent of Natural Loading	**1150%**	**828%**	**530%**	**1668%**	**1040%**	**911%**	**714%**

Table 4.32 Summary of Upper Elk River mass loading (tons/mi²/yr) by sediment source category for analysis time periods[1].

		Sediment Loading (tons/mi²/yr)						
	Source Category	**1955-1966**	**1967-1974**	**1975-1987**	**1988-1997**	**1998-2000**	**2001-2003**	**2004-2011**
Management	Low Order Channel Scour	94	33	19	30	45	17	20
	Bank Erosion	60	65	68	73	75	76	79
	Streamside Landslides	318	222	42	371	412	412	303
	Open Slope Shallow landslides	265	115	8	281	165	71	7
	Road-related Landslides	139	40	21	429	4	28	35
	Management discharge sites	42	84	112	91	55	55	55
	Skid Trails	5	17	15	17	36	21	21
	Treatment of Management Discharge Sites	0	0	0	0	18	5	33
	Road Surface Erosion	72	109	122	191	76	79	24
	Harvest Surface Erosion	3	8	2	7	8	6	5
	Total management-related Loading	**998**	**692**	**409**	**1491**	**894**	**771**	**584**
Natural	Bank Erosion	12	12	12	12	12	12	12
	Small Streambank Landslides	37	37	37	37	37	37	37
	Shallow Hillslope Landslides	42	42	42	42	42	42	42
	Deep seated Landslides	4	4	4	4	4	4	4
	Total Natural Loading	**95**	**95**	**95**	**95**	**95**	**95**	95
	Total Loading	**1093**	**788**	**504**	**1586**	**989**	**866**	679
	Percent of Natural Loading	**1150%**	**828%**	**530%**	**1668%**	**1040%**	**911%**	**714%**

[1]Calculated using a bulk density of 1.4 tons/yd³.

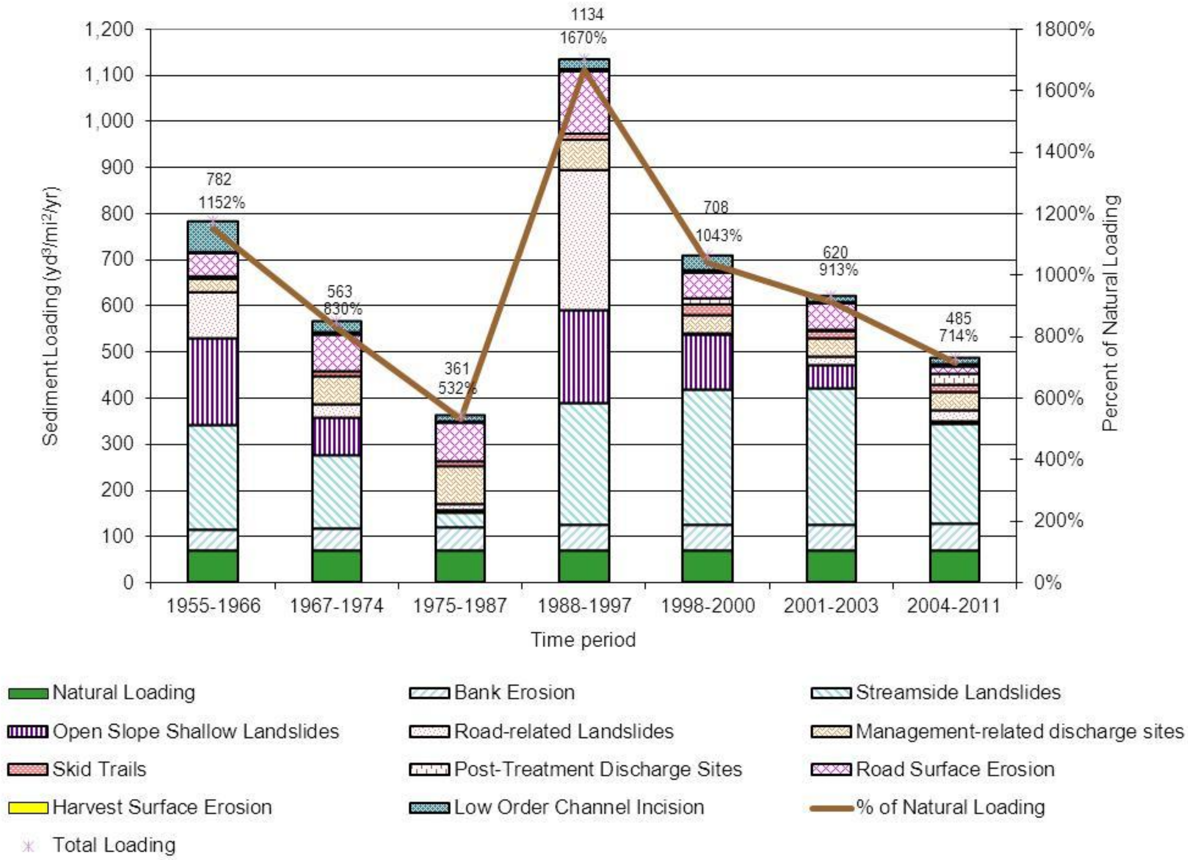

Figure 4.21 Upper Elk River loading by source category for analysis time periods.

4.7 Management-Related Sediment Loading Associated with In-Channel Storage

In Chapter 3 (Problem Statement), Regional Water Board staff identified significant stored sediment deposits as a primary driver of impaired beneficial uses and nuisance flooding conditions in the middle reach of Elk River which contains the low gradient portions of lower North and South Forks, and upper Mainstem Elk River near the confluence. The stored channel sediment contributes to physical conditions that limit the streams ability to pass water and sediment. This Source Analysis identifies the origin, timing and magnitude of hillslope sediment sources.

Table 4.33 presents estimated volume of stored material in different segments of the middle reach of Elk River based on calculations of cross-sectional changes, as presented in Section 3.3.

Table 4.33 Estimated magnitude of instream deposits stored in the Middle Reach of Elk River.

Reach description (downstream to upstream)	Upstream drainage area (mi^2)	Volume Deposition within Reach (yd^3)	Volume Deposition per Unit Area (yd^3/mi^2)
Upper Mainstem: Shaw Gulch to confluence	45.23	259,428	5,736
Lower North Fork: confluence to Browns Gulch	22.02	280,948	12,759
Lower South Fork: confluence to Toms Gulch	19.46	98,163	5,044

With respect to the sediment deposits within the area of the confluence, the targets identified in Chapter 6 are designed to define instream conditions supportive of beneficial uses and channel conditions capable of passing expected streamflows and sediment loads. The load allocations identified in Chapter 5 are developed to achieve the targets while reflecting the stream's current assimilative capacity.

The implementation framework identified in Chapter 7 presents actions necessary to recover beneficial uses of water, abate nuisance flooding conditions, and achieve the load allocations. Implementation actions include control measures for the hillslope sources identified in this source analysis as well as a strategy for channel restoration. Regional Water Board staff anticipates that restoration actions, beyond control of hillslope sediment sources, will be necessary to recover the stream's transport capacity in the middle reach of Elk River.

4.8 Conclusion

The Upper Elk River Sediment Source Analysis provides quantified estimates of the magnitude and timing of sediment loading from natural and management-related hillslope sediment sources and the loading associated with recent instream deposits in the depositional reaches. The natural loading estimates provide the basis for the load allocations to achieve the loading capacity, as described in Chapter 5. The management-related sediment loading estimates provide the basis for the load reductions to achieve those allocations, also described in Chapter 5.

CHAPTER 5. Upper Elk TMDL Sediment Loading Capacity and Load Allocations

Key Points

- The Upper Elk TMDL loading capacity is expressed as a percentage of natural background sediment loading equal to 120% (e.g., management-related allowable loading is 20% above background).
- There are zero point sources of sediment currently permitted in the Upper Elk River watershed; as such, the waste load allocation is set at zero (0).
- Management-related load allocations include hillslope sediment sources and instream deposits from the storage reaches of upper Elk.
- Attainment of the proposed TMDL will require 100% removal or remediation of recent sediment deposits from storage reaches in Upper Elk River prior to allocation of the full management-related loads.
- Upslope sediment inputs are to be reduced by 97% of 2011 levels.

5.1 Introduction

This chapter presents a synthesis of the data presented in the Introduction to the Upper Elk TMDL (Chapter 1), the Watershed Overview (Chapter 2), Problem Statement (Chapter 3), and Sediment Source Analysis (Chapter 4) of this Staff Report. The synthesis describes the linkage analysis (relationship) between pollutant loading and instream water quality conditions. The linkage analysis is fundamental in establishing the loading capacity of the impaired water and forms the basis of the TMDL for Upper Elk River.

The loading capacity of the Upper Elk River is defined as the total sediment load (natural and management-related), along with a margin of safety, that can be discharged into the Upper Elk River and its tributaries without impacting beneficial uses of water, causing an exceedence of water quality objectives or creating a nuisance condition.

The Upper Elk TMDL loading capacity is expressed in Equation 5.1:

$$\textit{TMDL} = \textit{Loading Capacity} = \sum(\textit{Natural Background} + \textit{Waste Load Allocation} + \textit{Load Allocation} + \textit{Margin of Safety}) \qquad \textbf{(Equation 5.1)}$$

Allocations are assigned to natural sources (natural background), point sources (waste load allocations) and to non-point sources (load allocations). In addition, the TMDL must include either an explicit or implicit "margin of safety" to account for uncertainties in the linkage analysis. The waste load allocation was set at zero (0) as no point source sediment discharges were identified in the Upper Elk River. In addition to contemporary nonpoint sources of sediment, the load allocation also includes consideration of instream stored sediment from past land use activities because it has significantly altered the assimilative capacity of the system for additional nonpoint source sediment loading.

5.2 Sediment Loading Capacity as a Ratio of Management-Related Sediment Loads to Natural Sediment Loads

As with most TMDLs for sediment on the North Coast, the loading capacity for the Upper Elk River is calculated as a ratio of the sediment loads discharged to the stream system from management-related sources to sediment loads discharged to the stream system from natural sources. In contrast to expressing the loading capacity as a fixed annual sediment load, the ratio approach has several potential advantages, including:

- The effects of land use changes can be detected better using a ratio than average annual sediment loading alone, because the ratio may vary less with storm history.
- The ratio could be measured periodically and provide an indication of progress toward meeting sediment reduction goals.
- The ratio may also be less dependent upon natural spatial and hydrologic variability.

Elk River is located in a portion of northwestern California which has a Mediterranean climate, relatively weak geology and an active tectonic setting. Therefore, natural sediment loads are highly variable and the native stream biota is adapted to large infrequent sediment pulses associated with natural disturbances (e.g., large storm events, wildfires, and major earthquakes). However, native stream biota is not adapted to the chronic increases in fine sediment load that is the result of land use activities that disturb vegetation cover and/or infiltration capacity of soil (e.g., road-related erosion, agriculture, construction, timber harvest, livestock grazing, etc.). Under the natural sediment input regime, fine sediment input would be very low in most years, and the amount of fine sediment stored in the channel would be rapidly reduced following large storm events back to levels favorable for spawning and rearing. As evidenced by past documented uses of water in the Upper Elk River, the natural sediment regime allowed for beneficial uses of water, including domestic and agricultural water supplies and cold water fisheries.

By expressing the loading capacity as a percentage of natural background, monitoring can be focused on measuring sediment discharge rates and in determining whether individual discharge sources are from natural sources or are a result of land management activities. This focus will allow a relatively efficient evaluation of implementation actions taken to attain of the TMDL load allocations.

5.3 Seasonal Variation and Critical Conditions

Consideration of seasonal variations and other types of critical conditions are required to ensure that water quality standards are protected during periods when those standards are most likely to be exceeded. The TMDL must describe how seasonal variations and other types of critical conditions, if present, are considered.

Sediment delivery in Upper Elk River has considerable annual and seasonal variability. The magnitudes, duration, and frequency of sediment delivery fluctuate depending on storm pattern and land use activities. The analysis accounted for this seasonal and yearly variability by calculating the sediment delivery over several analyses time periods which include both dry, average, and wet years, as well as significant erosion triggering events. This accounts for both the seasonal variation (winter producing the most sediment) and the critical conditions (large storms producing a large percentage of sediment).

Adverse effects on beneficial uses of water, including those associated with salmonid habitat and instream domestic and agricultural water supplies are the result of elevated suspended sediment loads as well as the accumulation and deposition of sediment within stream channels and floodplains. These effects result from both chronic inputs as well as from infrequent and large storms. Depending on sediment sources, the analyses quantify long-term averages, episodic inputs, and annual inputs, ensuring the most meaningful environmental conditions are considered for each source.

5.4 Linkage Analysis and Determination of Sediment Loading Capacity

The goal of the linkage analysis is to describe the process and method used to establish the relationship between pollutant loading and instream water quality response. The linkage analysis is also used to identify the loading capacity of the impaired water.

In order to determine the percentage of natural background sediment that is protective of water quality standards in Upper Elk River, multiple lines of evidence were evaluated. The lines of evidence considered for use in the Upper Elk TMDL include:

- Loading capacities established in other sediment North Coast TMDLs;
- Sediment loads that would attain the Basin Plan numeric water quality objective for turbidity; and
- Sediment loads that allow channel scour of instream deposits in areas where deposition has resulted in nuisance flooding conditions.

Review of Loading Capacities for Other North Coast Sediment TMDLs

Other sediment TMDLs developed for North Coast watersheds have used one or more of the following approaches to linking sediment inputs and instream attributes:

- A reference time period when beneficial uses were fully supported, namely when salmonid populations were robust;
- A reference watershed where water quality standards are attained (including water quality objectives for sediment) and where beneficial uses are fully supported; and
- Direct comparison of sediment supply to instream attributes (i.e., numeric targets) to estimate the needed reductions in existing loading rates.

The approach used in a particular TMDL depends, in large part, on the availability of data and the characteristics of the specific watershed.

As an example of a loading capacity based upon comparison with a reference time period, USEPA used this approach to calculate the TMDL for the Noyo River (USEPA 1999b). The TMDL for the Noyo River was set at the estimated sediment delivery rate for the 1940s. Because salmonid populations were substantial during this time period, which was assumed to be a quiescent period between the logging of old growth at the turn-of-the-century and logging of second growth in the middle of the 20th century, USEPA postulated that there could be increases above the natural amount of sediment and still maintain healthy watershed conditions. Analysis of Noyo River watershed sediment sources during this period indicates that there was about one part human induced sediment delivery for every four parts natural sediment delivery (i.e. a 1:4 ratio), or that total sediment loading was 125% of natural loading.

USEPA reached a similar result when they developed the loading capacity for the Trinity River in which reference watersheds were evaluated (USEPA 2001). For that TMDL USEPA used reference streams within the watershed to calculate TMDLs for all the subwatersheds in the Trinity River watershed (with the exception of the South Fork Trinity River). In this case, reference streams were subwatersheds in which some level of management had occurred yet the subwatershed still fully supporting beneficial uses of water. As with the Noyo, it appeared that in the Trinity River reference subwatersheds fish populations could be supported under TMDLs set at a level equivalent to 125% of natural loading.

USEPA compared instream conditions to sediment supply as a basis for loading capacities in the Van Duzen River and the South Fork Trinity River TMDLs. In the case of the Van Duzen TMDL the instream targets were expected to be attained under load reductions that achieved 107% of natural loading (USEPA, 1999). In the case of the South Fork Trinity TMDL, USEPA found that the instream targets could be achieved at 108% of natural loading (USEPA, 1998). This approach has not been used extensively on the North Coast. Iin part, this is because linking channel conditions to sediment supply is challenging since channel form and sediment deposits reflect the temporal and spatial integration of sediment inputs to and transport through stream channels. In addition to sediment supply, channel transport capacity and storage are influenced by: a) magnitude, duration, and frequency of high flows; b) channel slope and depth; and c) channel roughness, or elements that concentrate or disperse flow energy. For these reasons, time lags between sediment input and discharge may be several years to decades or more, and specific channel responses to changes in sediment supply may vary substantially.

Another example in which USEPA based loading capacities on instream conditions was in the Mad River TMDL. In this case, the numeric turbidity objective was used as the basis of the linkage analysis. The linkage analysis used in the Mad River TMDL was premised on a close correlation of suspended sediment to turbidity. The TMDL found that a 20% increase in naturally occurring background turbidity lead to a corresponding change of 20% in suspended sediment load. Additionally the TMDL concluded that reductions in suspended sediment load led to corresponding reductions in total sediment loading.

Based upon these findings, the Mad River TMDL established suspended sediment and sediment loading capacities at 120% of natural background sediment loads.

Table 5.1 provides a summary of the loading capacities resulting from linkage analyses conducted for sediment TMDLs on the North Coast. These loading capacities range from 105% of natural background to 341%, with a mean of 134%. The majority of other sediment TMDLs in the region (e.g., 14 of 19 TMDLs) has established a loading capacity of 125% of natural loading.

Table 5.5.1 Range of loading capacities developed for adopted North Coast sediment TMDLs.[90]

Watershed	Percent Natural Loading
Albion River	125%
Big River	125%
Eel River –Lower	125%
Eel River –Middle Fork	105%
Eel River – Middle Main	125%
Eel River –North Fork	125%
Eel River – South Fork	125%
Eel River – Upper Main	125%
Garcia River	341%
Gualala River	125%
Mattole River	125%
Mad River	120%
Navarro River	125%
Noyo River	125%
Scott River	125%
Ten Mile River	125%
Trinity River	125%
Trinity River- South Fork	108%
Van Duzen River	107%
Average	134%%

Evaluation of Sediment Loading Capacity Based on Attainment of the Turbidity Objective

The Basin Plan contains the following numeric water quality objective for turbidity:

> "Turbidity shall not be increased more than 20 percent above naturally occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof."

In accordance with the federal CWA, a TMDL is set at a level necessary to achieve applicable water quality standards. Using California's terminology, a TMDL is set at a level

[90] <http://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/> (as of February 22, 2013).

necessary to protect applicable water quality standards, including the beneficial uses, water quality objectives and anti-degradation policies. Simply put, TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards. The TMDL, in part, reflects the relationship between any necessary reduction of the pollutant of concern and the attainment of the water quality objectives and associated numeric targets.

Other applicable Basin Plan water quality objectives for sediment are narrative and conducting a linkage analysis specific to the attainment of each narrative objective is often prohibited by lack of sufficient data. The turbidity objective is unique in that it is the sole numeric objective for sediment contained within the Basin Plan. While it is necessary to track compliance with the narrative objectives for sediment, delay in response can make it difficult to correlate changes in the sediment parameters with land disturbing activities and waste discharges. However, these activities can result in an immediate and measureable turbidity response to erosion events, especially in the case of Upper Elk River which is largely comprised of erodible geologic formations that produce fine-grained sediment.

Federal law requires that all existing and readily available data be included in the evaluation of waterbody impairment and the development of associated TMDLs. In the case of Upper Elk River, extensive landowner and Regional Water Board staff resources were spent to develop, support and maintain monitoring stations instrumented to collect data relative to instream turbidity, suspended sediment, and streamflow, as well as the estimated suspended sediment load. These parameters were selected partially because the extensive timber harvesting activities in the Upper Elk River had resulted in impaired water quality. Monitoring these parameters also provided a record of attainment or exceedence of sediment-related water quality objectives.

In order to estimate the sediment loading capacity in Upper Elk River (as a percentage of natural loading) that would ensure attainment of the Basin Plan turbidity objective, staff evaluated turbidity and suspended sediment concentration data from the reference watershed in Upper Elk River. Appendix 5A describes staff's analyses which calculated and compared suspended sediment loads consistent with 1) naturally occurring background turbidity levels and 2) turbidity levels which are 20% greater than naturally occurring turbidity levels. Table 5.2 presents the comparison sediment loads and the estimated percentage of natural suspended sediment loading that would ensure attainment of the turbidity objective for 2004-2007, as well as the mean of those years..

Table 5.2 Comparison of 2004 to 2007 sediment loads and the estimated percentage of natural suspended sediment loading that would ensure attainment of the turbidity objective.

Year	Estimated Annual Suspended Sediment Load Based upon Naturally Occurring Background Turbidity in Reference Watershed ***(SSL*** $_{\textit{Background Turbidity}}$***)*** ($yd^3/mi^2/yr$)	Estimated Annual Suspended Sediment Load Based upon 120% of Naturally Occurring Background Turbidity ***(SSL*** $_{\textit{120\% Background Turbidity}}$***)*** ($yd^3/mi^2/yr$)	Percentage of Natural Suspended Sediment Loading in Conformance with Turbidity Objective
2004	11.64	14.36	123%
2005	22.32	28.23	126%
2006	33.06	38.13	115%
2007	10.74	14.15	132%
Mean	19.44	23.72	124%

As shown in Table 5.2, the percentage above natural suspended sediment background loading from 2004 to 2007 ranges from 115% to 132%, with a mean of 124%. Similar to the USEPA (2005) analysis in the Mad River TMDLs, staff recommends that to ensure an implicit margin of safety, 120% of natural suspended sediment loading be deemed in conformance with the turbidity objective over a range of streamflows and turbidity levels. Suspended sediment load is a portion of the total load. In the case of Upper Elk River, where the geologic formations produce primarily fined grained material, it is expected that the majority of the sediment loading is suspended. For any given change in total sediment load, a corresponding similar change in suspended sediment load is expected.

Suspended Sediment Concentrations to Initiate Channel Scour

The Basin Plan contains a narrative water quality objective for settleable material that states:

> Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses.

Exceedence of the objective for settleable material has resulted in significant channel deposition in portions of Upper Elk River, degraded channel conditions and reduced channel conveyance capacity. These conditions have adversely affected beneficial uses and cause a nuisance flooding condition. Monitoring data and recent staff evaluations, as described in Chapter 3, have documented the continued deposition of sediment at the current loads.

As described in Appendix 3D, a pilot modeling effort was conducted to test the performance of hydrodynamic and sediment transport models and the adequacy of the existing data for their application in a portion of the middle reach of Elk River. The pilot effort found that the models offered reasonable estimates of the observed water surface elevations and scour and fill within the modeled reach, and could provide appropriate and useful tools for assessing recovery actions at a broader scale (NHE and Stillwater, 2012).

Within the pilot modeling reach, results indicate that a 75% reduction in the measured 2003 suspended sediment concentrations would result in localized channel scour. Based on the hydrodynamic and sediment transport model predictions and inherent assumptions, the reduced sediment loads could lead to some form of channel recovery within the Elk River pilot project reach by transporting existing sediment deposits downstream. However, the fate of these sediment deposits on downstream reaches has not been assessed beyond the pilot project reach. An expanded hydrodynamic and sediment transport model that extends, for example, from the Middle Reach to Humboldt Bay, could inform fate and transport of stored sediment over a longer reach of the Elk River.

With the caveats above, use of the pilot modeling results suggest that at a minimum a 75% reduction in existing loading may be necessary to promote scour and restart the system towards dynamic equilibrium. The existing estimate of natural sediment loading is based on a long-term average for the period of 1955 to 2011, as is necessary for establishing the total maximum daily load. The source analysis estimates of natural loading are based upon long-term average hillslope inputs, rather than natural loading specific to the 2001-2003 time period. As such, the source analysis does not reflect the specific effects of rainfall, streamflow, and other factors present in 2003 that would have influenced the natural sediment loading rates in that year. This means that a 75% reduction in existing loading is not easily converted into a percentage of natural background, such that it is comparable to the estimates evaluated above (e.g., other sediment TMDLs and the estimate based on achievement of the turbidity objective). Consequently, it cannot be certain that a 75% reduction in existing loading will result in attainment of water quality objectives.

Clearly, full-scale modeling will provide a much more robust basis for understanding the relationship between hydrology and the fate and transport of sediment. When the results of full-scale modeling are available, they may inform a modification of the loading capacity estimate of this TMDL, while still ensuring attainment of all water quality objectives."

5.5 Upper Elk River Sediment Loading Capacity and TMDL

Staff compared the three lines of evidence described to estimate the loading capacity for Upper Elk River, including: 1) review of other North Coast sediment TMDLs, 2) loading to attain the Basin Plan turbidity objective, and 3) loading that would result in some amount of localized scour of management-related instream deposits. In order to ensure the selected loading capacity includes an implicit margin of safety, staff recommend an approach that is based on the most conservative interpretation relative to protection of beneficial uses. In this case, staff recommends establishing sediment loads in conformance with the turbidity objective approach, as follows.

The sediment TMDL for all stream reaches within the Upper Elk River watershed is set equal to the sediment load that corresponds with 120% of natural sediment loading.

The resulting sediment load associated with the loading capacity for the Upper Elk TMDL is calculated by Equation 5.2:

TMDL = Loading Capacity = (0 WLA) + 1.2 x Natural Sediment Loading **(Equation 5.2)**

Applying the natural sediment loading rate of 68 yd^3/mi^2 (Table 4.5) into Equation 5.2, the Upper Elk TMDL is calculated in Equation 5.3:

$$TMDL = 1.2 \times (68\ yd^3/mi^2/yr) = 81\ yd^3/mi^2/yr \qquad \text{(Equation 5.3)}$$

5.6 Margin of Safety

The Upper Elk TMDL incorporates a margin of safety (MOS) through use of conservative assumptions. The Upper Elk River loading capacity of 120% of natural loading is set to ensure protection of beneficial uses, attainment of water quality standards, and prevention of nuisance conditions.

Attainment of the numeric objective for turbidity provides the basis for the loading capacity established for the Upper Elk TMDL. The linkage analysis finds that on average and over a range of rainfall years, 124% of natural sediment loading would result in attainment of the turbidity objective. The loading capacity is thus set at 120% to ensure an implicit margin of safety.

TMDLs are established to be protective of the most sensitive beneficial use. Typically, in North Coast streams the most sensitive beneficial use to sediment/siltation impairments are those related to cold water fish. Review of adopted North Coast sediment TMDLs suggests that 125% of natural sediment loading could support robust salmonid populations. The Upper Elk TMDL is premised on the assumption that water quality conditions that fully support beneficial uses associated with salmonids would also ensure support of the domestic drinking water.

Exceedence of the narrative objective for settleable material has resulted in sediment deposition and nuisance flood conditions. TMDL implementation, including instream restoration activities, is expected to help recover conveyance capacity and ecosystem function. In combination, recovery of conveyance capacity and load reductions are anticipated to lead to recovery and ensure prevention of nuisance conditions. Should the full-scale hydrodynamic and sediment transport modeling, planned under the *Elk River Watershed Recovery Assessment and Pilot Sediment Remediation Project,* provide results indicating that a loading capacity less than 120% of natural background is necessary to achieve recovery, then the loading capacity established here will be re-evaluated.

5.7 Management-Related Sediment Load Allocations and Load Reductions

The load allocations for sediment in Upper Elk River include allocation of the loading capacity amongst natural sediment loading, management-related sediment loading, and a margin of safety (Equation 5.4). The management-related load allocation necessarily considers loading associated with hillslope sources as well as instream deposits within the storage reaches (Equation 5.5).

TMDL = (Natural Load Allocation) + (Management Load Allocation) + MOS (Equation 5.4)

Equation 5.4 can be evaluated to determine the management load allocation, with an implicit margin of safety included:

TMDL = 81 $yd^3/mi^2/yr$ = (68 $yd^3/mi^2/yr$ + 14 $yd^3/mi^2/yr$) (Equation 5.5)

Thus the total management load allocation can be expressed as:

Management Load Allocation = 14 $yd^3/mi^2/yr$ (Equation 5.6)
= Upslope Management Loading– Management-Related Instream Deposits Loading

As described in the Sediment Source Analysis, the estimated volume of the recent instream deposits was calculated for the storage reaches upper Mainstem, lower North Fork, and lower South Fork (Table 3.3). The loading associated with the instream deposits is presented in Equation 5.7 and reflects the recent sediment volume deposited within each storage reach, the upstream drainage area, and the time period over which to treat the material in accordance with the load allocations.

Instream Deposits Loading = (Volume stored material in middle reach) ÷
(Time period for restoration) ÷ (upstream drainage area) **(Equation 5.7)**

It is anticipated that the instream deposits could be cleaned-up in a 10 year time period (5 years for planning and permitting, and an additional 5 years for implementation). The estimated volumes and resulting sediment loading from instream deposits are presented in Table 5.3.

Table 5.3 Sediment volume and loading associated with instream storage of management-related sediment deposits in storage reaches of Upper Elk River.

Storage Reach description (downstream to upstream)	Upstream drainage area (mi^2)	Volume instream deposit (yd^3)	Instream deposit loading ($yd^3/mi^2/yr$)
Upper Mainstem: Shaw Gulch to confluence	45.23	259,428	574
Lower North Fork: confluence to Browns Gulch	22.02	280,948	1,276
Lower South Fork: confluence to Toms Gulch	19.46	98,163	504
Total Middle Reach	**45.23**	**638,539**	**2,354**

The ownership within each of the areas draining to the storage reaches was used to proportion the instream deposit volumes and loadings amongst the landowners therein (Table 5.4).

Table 5.4 Ownerships, volume (yd^3), and loading ($yd^3/mi^2/yr$) within drainage areas associated with storage reaches in Upper Elk River.

Storage Reach description (downstream to upstream)		Humboldt Redwood Company	Bureau of Land Management	Green Diamond Resource Company	Residential/ Non-Industrial
Upper Mainstem: Shaw Gulch to confluence	**Ownership**	76%	13%	7%	5%
	Volume (yd^3)	196,792	33,485	17,028	12,409
	Loading ($yd^3/mi^2/yr$)	435	74	38	27
Lower North Fork: confluence to Browns Gulch	**Ownership**	98%	0%	0%	2%
	Volume (yd^3)	275,329	0	0	5,619
	Loading ($yd^3/mi^2/yr$)	1,250	0	0	26
Lower South Fork: confluence to Toms Gulch	**Ownership**	50%	30%	15%	5%
	Volume (yd^3)	49,081	29,449	14,975	4,908
	Loading ($yd^3/mi^2/yr$)	252	151	77	25
Total	**Volume (yd^3)**	521,202	62,934	32,003	22,936
	Loading ($yd^3/mi^2/yr$)	1,938	225	115	78

At present, the loading associated with the instream deposits consume the loading capacity and preclude attainment of the management load allocation. Load reductions of the instream deposits through removal or reconfiguration of the instream deposits via implementation of recovery actions is necessary to alleviate nuisance flooding, to meet the numeric targets for channel conveyance and Basin Plan water quality standards.

In addition to load reductions from the management-related instream deposits within the storage reaches, management-related upslope sediment loads are significantly elevated over natural loads in Upper Elk River. Management-related upslope sediment sources load reductions of 97% from 2011 levels are necessary to achieve the management-related load allocation of 20% of natural. The management-related upslope allocations are set for individual land ownership. Alternative means of compliance may be proposed by landowners, either individually or cooperatively, to attain the management-related load allocations for Upper Elk River.

Staff has identified different time frames to achieve reductions from different sediment sources; the rationale for the time frames is described below.

- Contemporary management most- readily influences sediment loading from disturbed areas associated with harvest units, road surfaces, and treatment of management discharge sites. Practices to achieve load reductions from these sources should be implemented immediately and the load reductions should be achieved by 2018.
- Load reductions from management-discharge sites have been being implemented since 1999 under the Palco/HRC HCP, HRC CAOs, the GDRC WWDR, and the BLM Headwaters Forest Management Plan. Completion of load reductions from these sites is anticipated to be achieved by 2018.
- Management-related open slope and road-related landslides are influenced by slope stability. Measures have been in place since at least 2005 (PL and GDRC WWDRs) to evaluate how timber harvesting might influence stability and avoid harvest-related landsliding. Based upon recovery of root strength, it is assumed that the majority of slope stability is recovered within 15 years following harvest. Additionally, road-related landslides are controlled via storm-proofing and road maintenance techniques; these programs are well underway in Upper Elk River. Thus, staff anticipate that load reductions associated with harvest-related open slope and road-related shallow landslides are achievable by 2020.
- In-channel sediment sources, including bank erosion and streamside landslides, are relatively significant in the source assessment and may be difficult to control. These sources are influenced by past and present land uses and channel disturbance. There is not currently a program in place to ensure current land use activities prevent aggravation of these sources, nor to inventory watercourses and identify features, prioritize and schedule sediment minimization or mitigation measures. Staff believe that it is appropriate to allow a longer time period to achieve reductions from these in channel sources than the timeframe assigned to other source categories. As such it is anticipate that load reductions associated with in-channel sources will be achieved by within 20 years of establishing the Upper Elk TMDL (2033).

Table 5.5 describes the necessary load reductions to achieve the management-related loading allocations of 20% of natural sediment loading, as well as a schedule for attainment. Because the sediment source analysis had different methods for evaluating the 1955-2003 and the 2004-2011 time periods, the resulting sediment loadings may not be directly comparable. As such, staff’s best estimates for load reductions associated with both 2003 and 2011 time periods are provided in Table 6.4.

Table 5.5 Management-related load allocations and necessary percentage reductions from 2003 and 2011 management-related sediment loads.

Management-Related Sediment Source Category	2001-2003 Loading ($yd^3/mi^2/yr$)	2004-2011 Loading ($yd^3/mi^2/yr$)	Allocation ($yd^3/mi^2/yr$)	Percent Reduction from 2003 Loading	Percent Reduction from 2011 Loading	Schedule to Achieve Allocation
Management Sediment Discharge Sites	39	39	1.3	99%	97%	2018
Post-Treatment Sediment Discharge Sites	4	24	1.4	98%	97%	2018
Road surface erosion	56	17				
Harvest Surface Erosion	5	4				
Open Slope Shallow Landslides	51	5	1.0	99%	97%	2020
Road-Related Landslides	20	25				
Low Order Channel Incision	12	14	9.4	97%	97%	2033
Bank Erosion	54	57				
Streamside Landslides	294	217				
Skid Trails	15	15	0.5	97%	97%	2033
Total Management-Related Upslope Sediment Loading	**551**	**417**	**13.6**	**98%**	**97%**	**2033**
Total Management-Related Instream Storage Loading		**2,354**	**0**	**100%**	**100%**	**2023**

In addition to actions needed to resolve sediment-related threats to fisheries and water supplies, progress is also needed toward recovery of channel and floodplain conditions resulted from the storage of instream deposits from past and ongoing sediment discharges. The Regional Water Board recognizes the technical, institutional, and monetary challenges that each of the impacted residents and responsible party has faced and may face in designing and implementing measures to reduce fine sediment loads from Upper Elk River and to rehabilitate ecosystem function and restoration of channel capacity in the middle reach of Elk River.

The implementation program framework reflects the consideration and balancing of various relevant factors including, cost, equity, magnitude of impact, degree of management controls in place, feasibility, and probability of success.

CHAPTER 6. Numeric Targets

Key Points

- Staff proposes a suite of numeric target conditions (targets) for selected indicators which provide an interpretation of narrative water quality objectives. The proposed targets are consistent with water quality objectives and anti-degradation policies.
- Staff finds the natural and management-related hydrologic factors associated with sediment loads in Upper Elk warrant a new water quality objective for watershed hydrology which is based on watershed health and aquatic ecological functioning. Staff recommend the watershed hydrology objective be developed for application at either the watershed scale (i.e. Elk River), or regionally as appropriate.
- Hillslope numeric targets for the hillslope management-related sediment source categories are proposed that collectively describe hillslope conditions that will conform to Basin Plan water quality objectives and TMDL load allocations. Additionally, staff proposes targets for riparian areas and prevention of cumulative watershed effects.
- Instream numeric targets are proposed for indicators important to cold water habitat and migration. Conditions supportive of salmonids are anticipated to be supportive of water supplies.
- A proposed in instream numeric target for prevention of nuisance flooding is based upon historic channel conveyance capacity measurements by USGS.

In general, section 303(d) of CWA requires each state to establish a TMDL for waters within its boundaries for which effluent limitations are not stringent enough to implement applicable water quality standards. TMDLs, in turn, must be established at a level necessary to implement the applicable water quality standards. In short:

1. TMDLs require a quantitative numeric target necessary to implement existing water quality standards; and
2. While a TMDL's numeric target is an interpretation of existing water quality standards, it is not a water quality standard itself, and therefore, the processes required when adopting such standards do not apply.[91]

The USEPA also views TMDLs as containing waterbody-specific targets necessary to attain water quality standards. According to USEPA[92]:

> "[a] TMDL is a written, quantitative assessment of water quality problems and contributing pollutant sources. It identifies one or more numeric targets based on applicable water quality standards, specifies the maximum amount of a pollutant that

[91] Office of Chief Council (OCC) Memo (June 12, 2002), *The Distinction Between a TMDL's Numeric Targets and Water Quality Standard*s.
[92] USEPA, Region IX, Guidance for Developing TMDLs in California (January 7, 2000).

> can be discharged (or the amount of a pollutant that needs to be reduced) to meet water quality standards, allocates pollutant loads among sources in the watershed, and provides a basis for taking actions needed to meet numeric target(s) and implement water quality standards."

As part of the TMDL development process, numeric targets are often used as a means to express water quality objectives that are narrative in nature. Numeric targets are used to express, in quantitative form, hillslope and instream conditions that will likely result in achievement of applicable narrative water quality objectives. The numeric targets selected for use in the Upper Elk TMDL are based on hillslope and instream conditions associated with properly-functioning stream systems, including protection of beneficial uses of water and the prevention of nuisance flooding conditions. Numeric targets serve as the goal post from which TMDLs and associated load allocations are developed.

6.1 Water Quality Objectives for Sediment

With the exception of the turbidity objective, the water quality objectives related to sediment contained in the Basin Plan are primarily narrative in nature. The Basin Plan also contains a provision related to controllable water quality factors. Basin Plan water quality objectives and controllable factors provision as well as the sediment load allocations presented in this Staff Report were considered in the development of the numeric targets for use in Upper Elk TMDL.

As presented in the Problem Statement (Staff Report, Chapter 3) past regulatory and implementation actions in the watershed were insufficient to prevent nuisance and protect water quality and beneficial uses from the adverse effects of management-related sediment loads to Elk River. The Upper Elk TMDL propose the use of numeric targets in an effort to provide additional clarity in the development of waste discharge permits and implementation actions associated with achieving compliance with water quality standards and the abatement of nuisance flooding conditions in the watershed.

Given natural and management-related hydrologic factors associated with sediment loads in Upper Elk, Regional Water Board staff believe that an important component in preventing and recovering impaired water quality is to consider changes to hydrology at the watershed scale. Specifically,

1. The prevalence of soil piping in Upper Elk River poses a unique sensitivity to hydrologic modification which has contributed to their collapse, subsurface erosion, creation of in-channel sediment sources and sediment delivery downstream. Altered hydrographs and sediment delivery into downstream reaches has contributed to adverse impacts to beneficial uses, creation of nuisance conditions and non-attainment of water quality objectives for sediment.
2. The deposition of fine sediment in low gradient reaches of Upper Elk River has resulted in an increased frequency and magnitude of overbank flooding and a

nuisance condition for the community in Upper Elk River. The hydrologic connection between the channel and its floodplain is out of balance and the ecosystem is not functional to ensure expected flows, in combination with sediment loads, are able to be transported as they move downstream.
3. Hydrologic modification to the runoff patterns and drainage network in Upper Elk River has contributed to more rapid runoff and less infiltration of surface water into the soil mantle altering the natural groundwater recharge pattern. The decrease of base flow during the summer period adversely affects beneficial uses of water, including salmonid habitat and water supplies.

As described in Appendix 6A, staff recommend the following watershed hydrology objective be developed for application at either the watershed scale (i.e. Elk River), or regionally as appropriate, consistent with the peer reviewed *External Peer Review Draft Staff Report for Amendments to the Water Quality Control Plans for the North Coast and San Francisco Bay Regions to Protect Stream and Wetland Systems, External Peer Review Draft* (Ho and Livsey, December 1, 2009):

> "The hydrologic connectivity between headwaters and estuary, surface water and groundwater, and landscape, floodplain, and stream channel shall be protected to produce the pattern and range of flows necessary to support beneficial uses and a functional ecosystem."

The watershed hydrology objective would provide clarity to the connection between watershed hydrology, sediment loading, beneficial use protection, and prevention of nuisance. To ensure attainment of the load allocations, implementation actions necessary must consider past, present, and future influences to watershed hydrology.

Numeric targets Upper Elk were developed to provide interpretations of the sediment objectives as well as the proposed watershed hydrology objective.

6.2 Hillslope and Instream Target Conditions

TMDL numeric targets, while not independently enforceable, are useful in linking hillslope and instream conditions to narrative water quality objectives. It is staff's intent that the Upper Elk TMDL numeric targets, as appropriate, provide the basis for enforceable conditions in the development of future permitting actions in the Upper Elk River.

Numeric targets developed to address hillslope conditions in the Upper Elk TMDL include consideration of:

1. Controllable factors cause no further degradation of water quality, are reasonably controlled, and are brought into conformance with sediment objectives.

2. Management-related sediment loads are brought into conformance with the load allocations according to the timeline presented under the Implementation Framework (Staff Report Chapter 7).

Numeric instream targets are developed for the Upper Elk TMDL to describe instream conditions in which:

1. There are no adverse effects to beneficial uses or nuisance flooding conditions resulting from instream deposition of fine sediment in exceedence of the narrative objective for settleable material
2. There are no adverse effects to beneficial uses due to migration barriers resulting from controllable water quality factors.
3. There are no adverse effects to beneficial uses due to alteration of habitat conditions resulting from exceedence of the settleable material water quality objective.

The proposed numeric targets represent a conceptual linkage between hillslope erosion and aquatic ecosystem functioning, including the physical, chemical, and biological components of the aquatic system that support achievement of water quality objectives and protection of beneficial uses. Numeric targets were established based upon a number of considerations, including the ability of any specific target to provide useful information regarding the effectiveness of TMDL load allocations and the management measures implemented to achieve compliance with water quality objectives and protection of beneficial uses, including prevention of nuisance flooding conditions.

Hillslope Target Conditions

Sediment-related target conditions for the hillslope indicators in Upper Elk River are based upon the controllable water quality factors affecting each of the management-related sediment source categories identified in the Source Analysis (Staff Report Chapter 4) as well attainment of the TMDL management-related load reductions.

The sediment source categories and the controllable water quality factors which affect them are, as related to timber harvest activities, are described in the Sediment Source Analysis (Chapter 4) Table 4.6. For each of the management-related sediment source categories, the water quality factors affecting that source were evaluated from the standpoint of available sediment prevention and minimization measures. Target conditions were then developed to describe conditions in which sediment sources are likely to be controlled and TMDL management-related load reductions achieved. Table 6.1 presents the target conditions for hillslope sediment source areas and a discussion follows providing an overview of the scientific basis for the target condition.

The suite of hillslope targets are not enforceable but provide goal conditions indicative of conformance with load allocations and attainment of water quality objectives. These conditions are defined to provide guidance on conditions in which water quality impacts are prevented, minimized, and mitigated. It is anticipated that hillslope targets will inform the management-measures pursuant to the regulatory tools described in the *Upper Elk River TMDL Implementation Framework*, including existing prohibitions on threatened and actual sediment discharges, new and revised WDRs, and waivers.

Table 6.1 Hillslope numeric targets for Upper Elk River

Management-Related Sediment Source Category(s)	Numeric Hillslope Targets
Headward Incision in Low Order Channels	Zero increase in existing drainage network
Bank Erosion and Streamside Landslides	Decreasing trend in length of unstable channel
	Limit harvest-related peak flow increases in Class II and III watercourse catchment areas to 10% in 10 years
	All road segments are hydrologically disconnected from watercourses
Open Slope Shallow Landslides	Decrease in management-related open-slope landslide delivery in conformance with load allocation
Road Related Landslides	Improving trend in stability of roads to comply with load allocation
Deep Seated Landslides	Zero increase in discharge from deep seated landslide due to management-related activities
Management Discharge Sites and Skid Trails	No new management discharge sites created
	Treatment of all controllable management discharge sites
Treatment of Management Discharge Sites	Minimize post-treatment discharges to <0.25% of treated volume
Road Surface Erosion	Decrease road surface erosion toward load allocation
Riparian Areas	Improving trend in quality of riparian stands capable of providing: 1) delivery of wood and complexity to the channel for sediment metering, stabilization, and to provide habitat elements, 2) slope stability to minimize sediment delivery associated with landslide features, and 3) ground cover to ensure sediment control.
Cumulative Watershed Effects	The maximum timber harvest rate is 1.5% of a Class I subbasin area and 1.5% of ownership.

Headward Incision and Low Order Channels

Section 4.3 and Appendix 4C describes staff's evaluation of the current and natural drainage networks in Upper Elk River, including the drainage area upslope of channel heads and the drainage density within managed and unmanaged areas of Upper Elk River. Staff find that:

1) The drainage area associated with channel heads in unmanaged areas versus managed areas was 4.5 hectares versus 0.5 hectares
2) The drainage density associated with unmanaged versus managed areas was 5.5 mi/mi^2 versus 16.5 mi/mi^2, a three-fold difference attributable to management activities.
3) A combination of tractor and road crossings and hydrologic modification associated with canopy removal in unchanneled swales influenced the collapse of soil pipes, the formation of sink holes, and the headward incision of low order channels (Buffleben, 2009).

This empirical information has informed the development of the numeric hillslope target for the drainage network in Upper Elk of *Zero increase in the existing drainage network*. It is anticipated that implementation measures will include measures to avoid collapse or alteration of the soil pipe network, including but not limited to the following considerations in unchanneled swales: limitations on new crossings; prevention, minimization and mitigation of hydrologic modification; and promotion of stabilizing vegetation in areas of subsurface flow paths.

Bank Erosion and Streamside Landslides

The source analysis identifies the two primary management-related influences on bank erosion and streamside landslides are timber harvest and related activities and roads. These in-channel sources are anticipated to be the most difficult to control of all management-related sources and as such staff have assigned the longest time period of any management-related source (20 years) to attain load reductions (Chapter 5). Currently there is no program of implementation for their prevention, minimization, or mitigation. At best land managers and regulators attempt to avoid exacerbating them. Three hillslope targets were developed to address these sediment sources.

The first target is intended to define conditions in which loading from in-channel sources is reduced over time. As described in the sediment source analysis, field-based bank erosion and streamside landslide surveys were conducted along channel segments of known length, and quantifying the magnitude of sediment delivery as the summation of individual features. Additionally, a time period for delivery was estimated. Based upon these surveys, the sediment delivery volume per channel length per year was estimated ($yd^3/mi/yr$). The drainage density (mi/mi^2) was then multiplied by the estimate per channel length to estimate the sediment loading ($yd^3/yr/mi^2$). The first target related to bank erosion and streamside landslides is a *Decreasing trend in length of unstable channel*. Staff anticipate that a monitoring program will need to be developed to track loading from bank erosion and streamside landslides over time that will include measurement of length of unstable section of channel.

The second target related to bank erosion and streamside landslides is based upon the relationship between 1) canopy removal associated with timber harvesting, 2) the resulting changes in peak flows due to the hydromodification associated with the change in canopy, and 3) the suspended sediment load increases from in-channel sources due to increased peak flows.

Paired-basin studies conducted in Caspar Creek investigate the magnitude and causal mechanisms of the influences of timber operations on watershed hydrologic and sediment response. Caspar Creek is located 125 miles south of Elk River in coastal Mendocino County and is dominated by coast redwoods. Over the past 50 years a variety of useful studies have been conducted based upon the Caspar Creek.

Zeimer (1998) estimates an average increase of 27% in the 2-year recurrence interval peak flow, following clearcutting in the treatment watersheds. Keppler et al. (2008) estimates the elevated peak flows recover to pre-treatment levels after 10 years following clearcutting, the then increase again after pre-commercial thinning. Lewis et al. (2001) and Rice et al. (2001) find that peak flow increases are related to antecedent wetness, the proportion of watershed harvested, storm size and, and time since logging. Lisle et al. (2000) and Lewis et al. (2001) describe a regression equation that may be used to predict peak flow changes following timber harvesting.

Suspended sediment increases in harvested tributaries are correlated with increases in peak flows and peak flow volumes (Lewis 1998 and Lewis 2011). Reid et al. (2010) find that during years free of landslides, the major sediment sources appear to be from in-channel sediment sources. They also find that peak flow increases associated with timber harvesting result in increased drainage density. Cafferata (2012) estimated the suspended sediment loads associated with peak flow increases for Mendocino coast THPs and describes the relationship resulting from regression analysis of peak flows and associated suspended sediment loads in Caspar Creek as shown in Equation 6.1.

$$\Delta L = 100 * (1 + (\Delta Q_p) / 100)^m - 100 \qquad \textbf{Equation 6.1}$$

Where,

ΔL = percent change in suspended sediment load from in-channel sources
ΔQ_p = percent change in the peak flows, and
m = slope of linear regression line between log(L) and log (Q)

Equation 6.1 can be solved for a value of ΔQ_p that would limit the suspended sediment load associated with peak flow increases to 120% of the natural suspended load, as per the load allocations described in Section 5.5. As described in Appendix 6-B, m has a value of 1.25 for the Upper Elk River reference subbasin (Upper Little South Fork Elk) and a value of 2.52 for Caspar Creek (Cafferata, 2012), with a mean of the two available estimates of 1.88. Analysis indicates that to achieve the load allocation of 120% of natural sediment loading, the allowable incremental change in peak flows is 8% using the Caspar

Creek-derived value of ***m***, 16% using the value of ***m*** derived from the Upper Elk River reference subbasin, and 10% using the mean ***m*** of the two available estimates.

Appendix 6-C describes the Caspar Creek peak flow model (Lewis, 2001), for the 1.25-year recurrence interval events when in-channel sources are likely to be mobilized (Cafferata, 2012) and a wetness index value of 150[93]. . The results indicate that within any given catchment, regardless of size, canopy removal in a 10 year period should be limited to 17% using the Caspar Creek-derived value of ***m***, 32% using the value of ***m*** derived from the Upper Elk River reference subbasin, and 20% using the mean ***m*** of the two available estimates.

To control the increases in suspended sediment loads associated with in-channel sources (low-order channel incision, bank erosion, and streamside landslides) resulting from peak flow changes, staff propose the numeric target, *Limit harvest-related peak flow increases in Class II and III watercourse catchment areas to 10 percent in ten years.* Based upon application of the peak flow model, as documented in Appendix 6-B, staff finds that a canopy removal in excess of 20% in ten years would result in exceedence of the load allocations. Staff find that the calculation of proportion of canopy removal based upon clearcut equivalency, using the canopy removal coefficients provided in Table 4.28 is appropriate. Refinements to the canopy removal coefficients may be warranted, including a linkage between basal area, stand volume, and canopy.

Staff propose a third target associated with road-related bank erosion and streamside landslides. Roads can alter the hydrologic regime to watercourses by effectively increasing the catchment area that contributes runoff to the watercourse. A hydrologically connected road drains water directly to the adjacent stream, increasing the peak flows and suspended sediment loads in the stream. The hydrologic connectivity can be reduced by mimicking natural drainage as much as possible via road surface shaping and the installation of road surface and ditch drainage structures to disperse runoff onto hillslopes (USEPA, 1998; Weaver and Hagans, 1994). Staff propose the numeric target: *All road segments are hydrologically disconnected from watercourses.* While staff recognize that complete hydrologic disconnection is difficult, it is a target goal.

Hydrologic disconnection of roads may be accomplished with broader programs of stormproofing, which includes erosion prevention work designed to protect a road, including its drainage structures, fills and downslope areas, from serious episodic erosion during large storms and from chronic erosion during intervening periods (PWA). Major progress toward the target condition will be achieved through proper implementation of existing programs of stormproofing already in place on HRC, GDRC, and BLM lands. HRC's HCP requires that all their roads in Upper Elk River be stormproofed by 2018.

[93] The wetness index is a measure of the watershed's wetness of the day prior to the onset of the storm. As part of development of WWDRs in Upper Elk River, Regional Water Board staff (2005) conducted analyses of wetness index values based upon the measured Caspar Creek streamflows. The analyses resulted in a recommendation to use the median value, 150.

Open Slope Shallow Landslides

As documented in Chapter 4, management-related open slope-landslides have been among the dominant sediment sources to Upper Elk River. Shallow open-slope landslides may be influenced by a variety of factors related to timber harvesting, including reductions in stability due to loss of root strength, alteration of pore water pressure, and topographic and drainage alterations associated with ground-based operations. Staff proposes the numeric target, *Decrease in management-related open-slope landslide delivery in conformance with load allocation.* Identification of areas susceptible to slope failures using terrain mapping, landslide inventories, and site specific geotechnical slope stability assessment can inform appropriate levels of protection from management-related reductions in stability. These tools, combined with objective and repeatable methods to predict potential landside hazards and identify activities compatible with attainment of water quality standards, are necessary to ensure attainment of the load allocations for open-slope shallow landslides.

Following document review, a field tour, and workshop focusing on evaluation of measures implemented with the THP review process, the Independent Science Review Panel (ISRP 2003) found that it could not offer assurance that pre-harvest field inspections, even when conducted by licensed geologists are sufficient to address the direct and cumulative effects on water quality. The ISRP (2003) described that peer reviewed studies have shown that experienced geologists can produce strikingly different maps of landslide hazards in the same area, with spatial mismatch rates as high as 80% when maps made by three different groups of geologists are compared. A compounding factor is that there is no formal process for impartial third party review of these subjective maps. More uncertainty is introduced when geologists use simple field inspections in an attempt to predict the effect of timber harvesting on slopes that have not yet failed. A rigorous evaluation of pre- and post-harvest slope stability for various land management, climatic, and seismic scenarios would require undisturbed soil sample collection, laboratory testing, and quantitative slope stability analysis which can be prohibitively expensive and have its own significant environmental impacts (e.g., access roads for drilling rigs).

The ISRP (2002) advised that rate of harvest limitations based upon empirical sediment budget approach was sound while a larger effort to develop landslide hazard maps was undertaken in support of TMDL implementation. In 2006, the Regional Water Board developed waste discharge permits for Upper Elk River based, in part, upon the empirical sediment budget approach (Appendix 4-B).

Under TMDL development efforts, the Regional Water Board pursued development of landslide hazard maps in which Stillwater applied stability models and tested the results with verified landslide locations. The modeling effort is documented in the report, *Landslide Hazards in Elk River* (Stillwater 2005) and is included as Appendix 6-D. Using the LiDAR DEM for Upper Elk (as described in Appendix 2-B), Stillwater employed grid-based probabilistic and deterministic physically-based hillslope stability modeling approaches to predict potentially unstable areas and objectively test model predictions of potential instability by relating predicted instability to observed landslide occurrence documented in landslide inventories.

As described by Deitrich et al (2001), Stillwater evaluated the fraction of the area encompassed by a model-predicted potential instability value relative to the number of mapped landslides correctly predicted by that instability value. The resulting model outputs could be used individually or integrated into a single hazard map. In either case, relative stability index values should be based upon the validation results.

Use of a landslide hazard map, in combination with interpretation of and improvement on the hazard mapping predictions by field geologists, is anticipated to be valuable in informing decision making in timber harvest planning and review and ensuring load allocations are achieved. Measures should be taken to ensure that timber harvest operations are avoided and or minimized in areas of predicted lower stability. The allowable activities within the hazard categories should reflect the uncertainty associated with stability estimates therein. Timely investigation of factors influencing landslide occurrence and effectiveness monitoring over time can help to reduce uncertainty and refine the activities compatible with the load allocations. However, because landslide triggering hydrologic and seismic events are episodic and infrequent, there is likely to be delay in reliable measures of landslide reduction effectiveness.

Road Related Landslides

Similar to open-slope shallow landslides, road-related landslides have been an important component of the sediment delivery to streams throughout the analysis time periods (Chapter 4). Road construction and site evaluation standards have evolved over time. Large portions of the road network were built prior to the availability of tools and equipment to ensure proper location, layout, construction, etc. As such, portions of the road network remain vulnerable to road-related landsliding.

Staff proposes the numeric target, *Improving trend in stability of roads to comply with load allocation.*

As described in the above section on bank erosion and streamside landslides, ongoing programs of road stormproofing can greatly improve the stability of roads through erosion prevention work designed to protect a road, including its drainage structures, fills and downslope areas, from serious episodic erosion during large storms. As part of this effort, unstable sections of road should be identified and treated, going a long way toward attaining the target.

Use of a landslide hazard map, in combination with interpretation of and improvement on the hazard mapping predictions by field geologists, is anticipated to be valuable in identifying existing road segments that may be prone to failure, identifying appropriate treatments and ensuring load allocations are achieved. New road construction should be minimized and project proponents should demonstrate that stability has been evaluated.

Deep Seated Landslides

Sediment loading associated with deep seated landslides was not quantified under management-related sediment source categories in Section 4.4. There were no reliable means of estimating the management influence on the rate of movement of deep seated features. Further, shallow-landslides at the toes of deep-seated features were included in the landslide inventories and quantified in either natural or management-related loading. Staff propose the numeric target, *Zero increase in discharge from deep seated landslide due to management-related activities*.

As identified by Stillwater (2005), there has not been a comprehensive mapping of deep seated landslide features and their relative activity level in Upper Elk River. Identification of features is imperative to ensuring that management activities do not exacerbate their sediment delivery. With the advent of high resolution topographic data from LiDAR, techniques for evaluation of surface roughness assist in the prediction of locations of deep seated features (Roering et al., 2006). However, their locations need to be validated using mapping data (Stillwater, 2005). A coordinated effort in Upper Elk should be made to apply and validate predictive tools for locating deep seated features.

Additionally, hydrologic modifications capable of influencing sediment delivery associated with deep seated features should be prevented for new projects, minimized where past management modifications have resulted in hydrologic changes, and mitigated where possible. At locations of deep seated features with recent activity, evaluation for feasible mitigation measures should be conducted and those measures should be implemented and monitored for effectiveness.

Management Discharge Sites and Skid Trails

Management discharge sites, as evaluated in the Sediment Source Analysis, are erosion features that discharge (or have the potential to discharge) sediment in violation of applicable water quality requirements, are caused or affected by human activity, and will respond to management measures. This definition is synonymous with "controllable sediment discharge site" as used in the timber-related waste discharge requirements adopted by the Regional Water Board for the Elk River watershed (NCRWQCB, 2005). By definition, some treatment is possible at these management-related sites. Discharge sites include sites associated with watercourse crossings, roads, skid trails, gullies, road-related and non-road-related landslides. Typically, these sites are treated by removing some volume of fill material and then treating the channel and excavated slopes to minimize post-treatment sediment delivery.

Staff proposes two targets associated with management discharge sites and skid trails. First, *No new management discharge sites created.* With proper landuse planning and implementation, it is anticipated that the creation of new sites can be avoided. It is anticipated that sediment control measures can be effective to prevent sediment runoff from occurring and from preventing sediment that has runoff from delivering to a watercourse.

Second, *Treatment of all controllable management discharge sites*. To achieve this target, existing sites must be included in an inventory that is updated over time. Controllable management discharge sites must be prioritized based upon threat to water quality and other considerations. The sites must be scheduled for treatment with feasible erosion control practices implemented to 1) prevent sediment from reaching a watercourse and 2) minimize sediment discharges that cannot be prevented.

Significant effort has been put forth to develop and implement programs to identify, prioritize, treat and monitor existing management discharge sites in Upper Elk River. On HRC ownership in the Elk River, the program is implemented through a series of CAOs [94] and on a THP by THP basis pursuant to enrollment under their WWDR[95]. The program on GDRC lands is implemented on a THP by THP basis pursuant to their WWDR[96]. On land controlled by the BLM, the program is implemented through the Headwaters Forest Management Plan[97]. On non-industrial timber lands the program is implemented within THPs[98] and Non-Industrial Timber Management Plans (NTMP),[99] and on harvest areas and roads appurtenant to the harvest operations. Under these ongoing programs on HRC, GDRC, and BLM Lands, the majority of the high priority sites have been treated. Efforts to treat the lower priority sites are anticipated to continue at a schedule consistent with the load allocations.

Treatment of Management Discharge Sites

While imperative to address management sediment discharge sites, their treatments have resulted in further discharge of sediment. In addition to attaining the load allocation for management discharge sites and their treatment, staff propose a numeric target of, *Minimize post-treatment discharges to <0.25% of treated volume.* This target recognizes that some discharge may be challenging to avoid when treating stream crossings in remote areas of the forested landscape. However, it provides a goal for land managers to attain, especially over a range of flows. It also acknowledges that difficulty increases with the magnitude of sediment treated at the site. To attain the goal, it is vital that the treatment program include proper site evaluation, design, equipment, timing, erosion control, oversight, and erosion control maintenance.

Road Surface Erosion

Road surface erosion can be a chronic source of sediment delivery to streams. Staff proposes the numeric target*, Decrease road surface erosion to comply with load allocation*. Attainment of the target is anticipated through prevention and minimization measures.

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94 Order No. R1-2004-0028 (South Fork Elk River and Mainstem Elk River) and No. R1-2006-0055 (North Fork Elk River) (as amended by Order No. R1-2008-0100 to reflect new ownership).

95 Order No. R1-2006-0039 (as amended by Order No. R1-2008-0100 to reflect new ownership).

96 Order No. R1-2006.-

97 The United States Department of the Interior, Bureau of Land Management and California Department of Fish and Game Management Plan for the Headwaters Forest Reserve (2003).

98 Order No. R1-2004-0030, and Order No. R1-2009-0038.

99 Order No. R1-2009-0038.

Reduction in road density, especially those roads that are difficult to maintain or treat, will reduce the total length of road that is susceptible to road surface erosion. Surface treatments to protect the road surface and effectively limit sediment generation is imperative, especially in Upper Elk where the geologic formations produce predominantly fine sediment. Surface treatments can range from pavement to rock to mulch (e.g. straw or slash), to planting (e.g. grass or trees). The appropriate surface treatment is expected to vary depending on threat to water quality and the timing and nature of road uses. Staff recommends that all road segments have some level of surface treatment.

Treatment of road surface drainage for sediment removal prior to delivery to a watercourse is expected to be necessary to attain the target. Filtration and settling can be effective means of treatment. Again, due to the fine grained particles generated in Upper Elk River, their removal can be difficult and their removal may require creative solutions.

Use of roads during the wet period can result in sediment generation and require additional maintenance of drainage structures. Staff recommend that a decrease in the use of roads during the winter period will help to attain the target. HRC, GDRC, and BLM all have existing programs to limit winter use of roads as a means of controlling surface erosion. Attainment of the target likely warrants continual reevaluation of the limitations, including winter uses for activities other than log hauling (e.g. trucks of light-duty trucks and all-terrain vehicles used for efforts such as monitoring and THP layout)

Riparian Areas

The area of vegetation near streams is commonly referred to as a riparian zone or area. As used in the Upper Elk TMDL, riparian zones are defined as transitional areas between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. Riparian zones are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian zones are adjacent to all perennial, intermittent, and ephemeral streams, lakes, wetlands, and estuarine-marine shorelines (adapted from NRC 2002).

A riparian zone helps maintain healthy stream ecosystems and supports beneficial uses in the following ways (Reference):

- Stabilizes banks through provision of root cohesion on banks and floodplains
- Filters sediment from upslope sources
- Filters chemicals and nutrients from upslope sources
- Supplies appropriate large wood to the channel which maintains channel form and improves in-stream habitat complexity

- Helps maintain channel form, instream habitat, and an appropriate sediment regime through the restriction of sediment inputs or metering of sediment through the system
- Moderates downstream flood peaks through temporary upstream storage of water
- Helps maintain cool water temperatures through provision of shade and creation of a cool and humid microclimate over the stream
- Provides food resources for the aquatic ecosystem in the form of leaves, branches, and terrestrial insects

In order to achieve the targets associated with management sediment source categories, staff propose a numeric target for riparian areas, *Improving trend in quality of riparian stands capable of providing: 1) delivery of wood and complexity to the channel for sediment metering, stabilization, and to provide habitat elements, 2) slope stability to minimize sediment delivery associated with landslide features, and 3) ground cover to ensure sediment control.*

Palco (2004) evaluated the delivery distance of shallow landslides to different stream classes for the 1988-2000 photo period, providing information pertinent to the design of riparian areas that may protect streams from delivery of sediment originating from shallow landslides. The data indicate that sediment delivered from near stream (within 400 feet of a stream) landslides is distributed differently amongst stream classes, with 36% of delivery to Class I watercourses (fish-bearing streams), 26% to Class II watercourses (streams with non-fish aquatic species), and 38% to Class III (ephermal) watercourses. Figure 6.1 illustrates the cumulative percentage of landslide sediment delivery as a function of delivery distance from the streams.

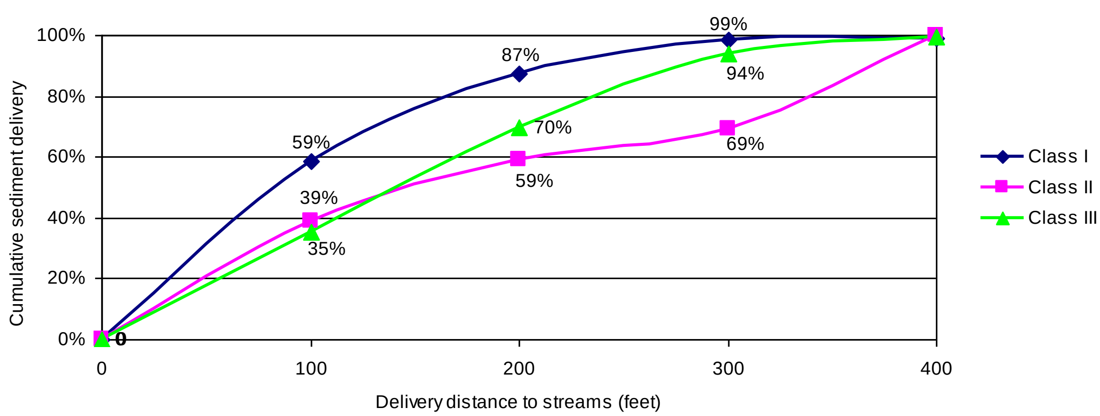

Figure 6.1 Cumulative sediment delivery volume from shallow landslides as a function of distance to watercourse for the 1988-2000 (Palco, 2004).

The Forest Ecosystem Management Assessment Team (FEMAT) Report (1993) evaluated the minimum distance from streams necessary to restore and maintain required habitat for aquatic species on Federal Lands in the Pacific North West. MANTEC (1996) complimented FEMAT, emphasizing that salmonid conservation can only be achieved by maintaining and restoring watersheds, particularly riparian processes and their natural rates. The FEMAT report identified riparian "reserves" to be areas where land was to be managed for the primary purpose of maintaining the health of aquatic and riparian-dependent ecosystems. The report concluded that in order to ensure restoration and maintenance of instream conditions supportive of aquatic species, no programmatic harvest, road construction or use, grazing, etc. should be allowed within the riparian zones. However, the report did acknowledge that in some cases modification of riparian stands may be beneficial to accelerate restoration.

FEMAT defined the width of the riparian reserve areas based upon site-potential tree heights, which were defined as "the average maximum height of the tallest dominant trees (200 years or older) for a given site class," and are generally 170-200 feet tall. Using a similar stream classification system used in the California Forest Practice Rules (e.g. Class I (fish bearing), Class II (non-fish bearing), and Class III (ephemeral)), FEMAT identified the minimum riparian reserve areas to be two site potential tree heights (340-400 foot) for Class I and II watercourses and one site potential tree heights (170-200 foot) for Class III watercourses. FEMAT selected these widths as minimums, recognizing the potential economic impact of larger buffers that prior studies had identified as important. A generalized curve relating to the cumulative effectiveness of the riparian forest at providing a variety of functions to streams, as a function of buffer width, is presented in Figure 6.2 (FEMAT, 1993).

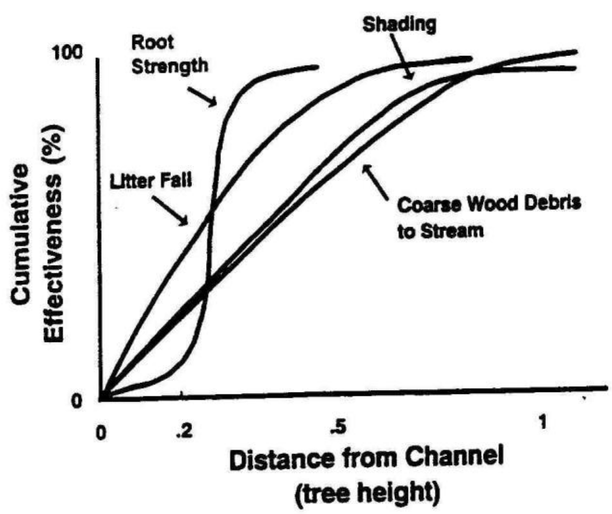

Figure 6.2. Riparian forest effect on streams as a function of buffer width (FEMAT (1993) as presented by MANTEC (1996)).

While important functions of the near-channel environment may be achieved by narrower buffer zones (e.g. wood input), additional width is required to protect the riparian area from accelerated blow-down and ensure that the appropriate age distribution is sustained within the riparian area. Additionally, FEMAT found that the identified buffers were minimums to ensure sediment filtration within undisturbed land to preclude chemicals and nutrients from being introduced to the stream as a result of upslope management activities. While temperature is not currently an identified impairment in Upper Elk River, maintenance of microclimate, especially under climate change conditions, is crucial to ensure a sustaining environment.

FEMAT found that modifications to the riparian reserves would limit their ability to sustainably provide the necessary functions. Periodic harvesting of individual trees from within the areas capable of contributing woody debris to channels would lead to reduction in volumes and sizes of woody debris in channels, thus altering channel form, instream habitat, sediment transport regimes, and flood hydraulics. Accelerated blow-down could result in wood debris sizes that are likely to be smaller than appropriate, and the channel may shift between phases of severe overloading of debris and phases of depletion after the pulsed input has decayed and before the new stand is old enough to begin contributing significant wood. Excessive rates of sediment input would accompany such pulsed inputs of woody debris.

Cumulative Watershed Effects

In 2002, the Regional Water Board convened an Independent Scientific Review Panel (ISRP or Panel) to address questions designed to assist the Regional Water Board to fulfill its mission to protect and restore sediment impaired beneficial uses in Elk River and four other nearby watersheds. In Phase I, the Panel was asked to identify and evaluate a set of actions that could be initiated in the short term to protect beneficial uses and reduce flooding in all five watersheds. In addition, the Panel was asked to evaluate the technical strengths and weakness of several approaches to calculating rates of timber harvest that would not impede recovery from excess sediment loads and would not cause or contribute to exceedence of water quality objectives. In response to these directives, the Panel produced a report entitled, "*Final Report on Sediment Impairment and Effects on Beneficial Uses of the Elk River and Stitz, Bear, Jordan and Freshwater Creeks*" on December 27, 2002, and presented its findings at the January 23, 2003 Regional Water Board meeting.

In Phase II, the Regional Water Board specifically requested that the Panel review and comment on the levels of protection in the HCP/SYP/THP processes and the effectiveness of existing mitigation measures, especially the extent to which the existing HCP/SYP/THP processes address rate of recovery of beneficial uses in the sediment impaired watersheds. The Regional Water Board anticipated that the Panel's Phase II findings would be used to inform the scientific basis for the development of TMDLs in all five watersheds, including Elk River.

The ISRP found that without effectiveness monitoring and periodic assessment, there is no way to know whether mitigation strategies are effective. The Panel also emphasized that neither its analysis nor any other analysis could predict with certainty what combination of measures and logging rate restrictions would ensure the protection of water quality and recovery of impaired watersheds. The best that could be done is to postulate a plan based on the best available information; continually test the plan using a combination of compliance, effectiveness, and trend monitoring; and revise the plan in a timely and appropriate manner based on monitoring results.

The density of the road network and the intensity of use are closely linked to harvest rate. Reliance on best management practices (BMPs), rather than limiting harvest rates, has been the trend in Northern California forest practices. However, due to lack of effectiveness monitoring of individual BMPs, especially those identified under the California Forest Practice Rules and the Habitat Conservation Plan for Pacific Lumber Company Lands, it is difficult to rely solely on BMPs to ensure cumulative watershed effects are avoided and water quality standards are achieved (EPA, 2001; ISRP, 2002 & 2003; Klein 2011).

Klein et al. (2011) found that of the natural and management-related variables affecting erosion, timber harvest rate over the prior 10-15 year period was the most significant variable to explain chronic turbidity levels in North Coast watersheds, with turbidity impairment rising with increasing rate of harvest. Comparing 28 North Coast streams of varying drainage areas, Klein et al. (2011) used the 10% exceedence probability turbidity as a single measure of chronic exposure for salmonids as it represents turbidity levels during between-storm winter base flows.

In a previous study, Klein et al. (2008) found a strong correlation between the 10% exceedence probability for turbidity and timber harvest rate in the prior 0-15 year period. The 10-15 year time period likely included effects of reduced hillslope stability induced by root strength minimums following harvest. Gullying and landsliding can result a decade or more following harvest (Reid , 2010). Klein et al. (2011) found that the 28 watersheds clustered into groups, including: pristine (unharvested), legacy (not harvested in past 15 years), low harvest rate (less than 1.4% annual harvest 10-15 years ago), and high harvest rate (greater than 1.5% annual harvest 10-15 years ago) (Figure 6.3).

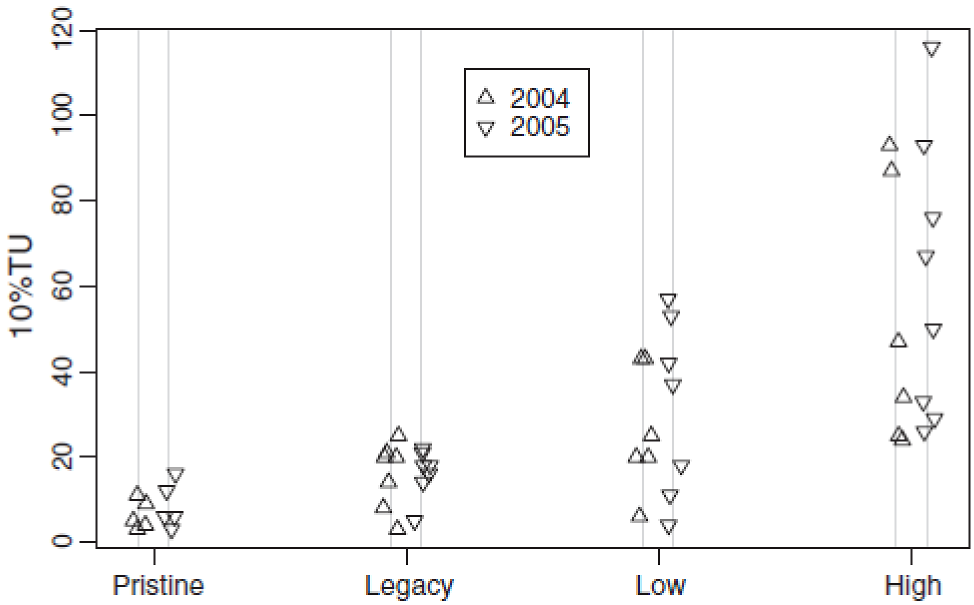

Figure 6.3 Grouping of North Coast watersheds based upon timber harvest rate category (x-axis) and 10% exceedence turbidity values (y-axis) (Klein et al., 2011).

Figure 6.4 shows the observed 10% exceedence probability turbidity versus that predicted by regression analysis on drainage area and clearcut equivalent area for the period 10-15 years before the Hydrologic Year 2005 turbidity record (Klein et al. 2011). For the reader's convenience, staff has circled the stations located within Upper Elk River, all of which fall above the prediction line, indicating that they have a stronger chronic turbidity signature for a given harvest rate and drainage area than other streams in the study.

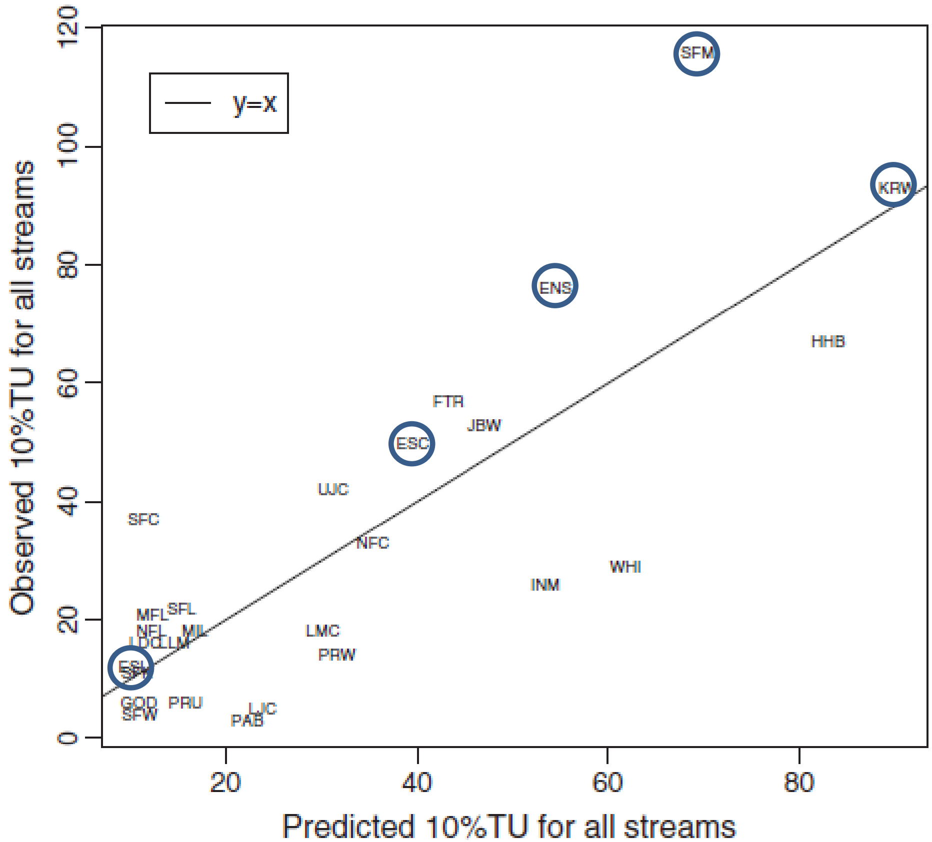

Figure 6.4 Observed 10% exceedence probability turbidity compared to those predicted by regression on drainage areas and clearcut equivalent area for the prior period 10-15 year period (Klein, 2011)

To ensure that timber harvest rate does not preclude recovery, water quality conditions supportive of salmonids and water supplies, and prevention of nuisance conditions, nor cause further cumulative watershed effects, staff propose a numeric hillslope target relating to timber harvest rate: *Within a Class I subbasin, and within an individual ownership, the maximum average annual timber harvest rate is 1.5%*.

The target describes a goal for the maximum harvest rate. Until recovery is achieved load reductions to attain the TMDL, staff recommend that timber harvest rate be commensurate with progress toward achieving the allocations. Figure 6.4 illustrates how timber harvest may progress toward a maximum of 1.5% as effective measures to achieve load reductions are implemented. Staff recommend that harvest rate be calculated as clearcut equivalency based on proportion of canopy removed via the silvicultural treatment. It is expected that the combination of riparian protections and landslide hazard mapping will result in timber harvesting limitations that will largely achieve this target.

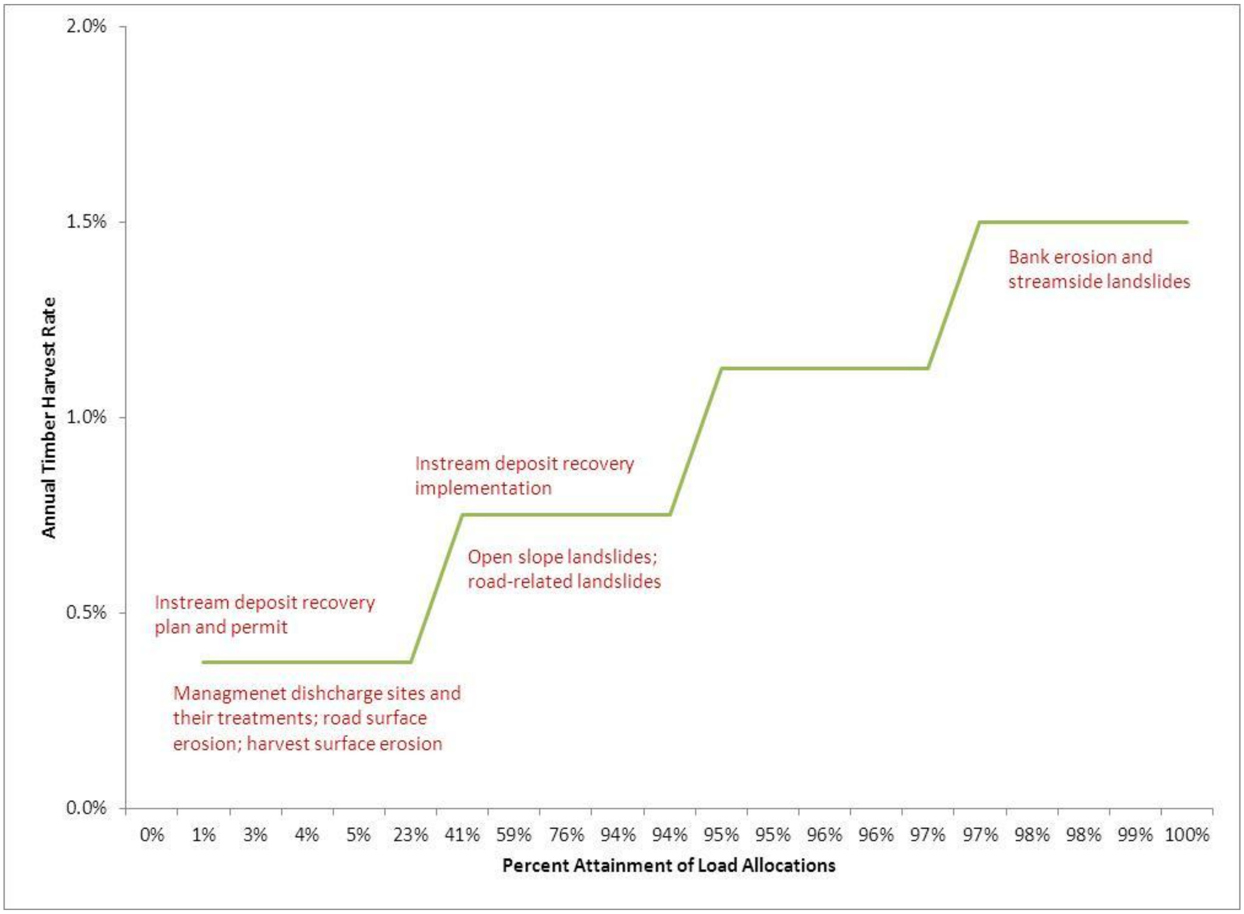

Figure 6.5 Illustration of a rate of harvest commensurate with attainment of load allocations and consistent with achieving the target for cumulative watershed effects.

Instream Indicators and Target Conditions

Salmonid Habitat

The primary beneficial uses of water that are degraded by sediment in Upper Elk River are domestic and agricultural water supplies and cold freshwater fisheries. The *Desired Salmonid Freshwater Habitat Conditions For Sediment-Related Indices* report (Desired Conditions Report) (Fitzgerald 2006) summarizes instream sediment conditions suitable for salmonids. The Desired Conditions Report was submitted by the Regional Water Board for scientific peer review in 2004 and released for public review in the same year. Responses to comments were prepared and released in 2006. The report discusses instream indicators, their desired conditions, and their application for the control of sediment discharge and protection of cold water fisheries in the North Coast Region, as represented by the sediment-related life cycle requirements of salmonids. The report also contains a summary of the relevant literature to support the selected indicators, their importance in characterizing instream conditions suitable for salmonids, and the desired condition values for each indicator. Staff has selected indicators and targets which are suitable for Upper Elk River from the Desired Conditions Report.

Explicit sediment-related instream indicators and targets specific to the recovery of hydrologic and geomorphic conditions supportive of agricultural and domestic water supply are not proposed. It is staff's professional judgment that the recovery of instream conditions supportive of the life cycle requirements of salmonids will simultaneously result in instream conditions also suitable to support instream water supplies. As a general matter, the water quality conditions necessary to support agricultural and domestic water supply include: pool depths great enough to accommodate water supply intakes without entraining sediments from the bottom or air from the top (e.g., approximately 4 feet) and suspended sediment levels low enough to prevent damage to the pumps (e.g., less than 20-40 mg/L). The TMDL is designed to return the hydrologic and geomorphic conditions of Upper Elk River to a dynamic equilibrium similar to that found historically. For example, pool depths in the location of water intakes have historically been between 3 and 12 feet (RCAA 2003, K. Wrigley, Pers. Com. 2012). Historically, turbidity levels suitable for water intakes have recovered within 3-5 days following a storm (K. Wrigley, Pers. Com. 2012).

Table 6.2 identifies the instream salmonid habitat indicators and targets selected for use in the Upper Elk TMDL. A target is included for each of the indicators of interest. In several cases, targets are expressed as improving trends, because information on watershed processes is not adequate to develop numeric thresholds specific to the Elk River watershed.

Table 6.2 Instream habitat indicators and target conditions for sediment[100]

Indicator	Target Condition	Applicability	Monitoring/Sampling Notes
Percent Fines	≤ 14% fines < 0.85 mm in diameter. ≤ 30% fines < 6.40 mm in diameter.	Wadeable streams and rivers with a gradient < 3%.	Monitoring should use a McNeil sediment core sampler similar to the specifications found in *Success of Pink Salmon Spawning Relative to Size of Spawning Bed Materials* (McNeil and Ahnell, 1964), except the diameter of the sampler's core should be at least 2-3 times larger than the largest substrate particle usually encountered. Monitoring should occur according the protocols found in *Stream Substrate Quality for Salmonids: Guidelines for Sampling, Processing, and Analysis* (Valentine, 1995), and use the methodology for the redd or pool/riffle break sampling universe. A 0.85 mm a 6.40 mm sieve should be used during sample processing. The wet volumetric method is recommended with the use of the wet volumetric method and the dry gravimetric method on 10% of the samples.
Pebble Count (D_{50})[101]	D_{50} of 65-95 mm	Streams with slopes between 1 and 4 percent.	Monitoring should be done according to protocols found in *Testing Indices of Cold Water Fish Habitat* (Knopp, 1993).
Embeddedness	Increasing trend in the number of locations where gravels and cobbles are ≤ 25% embedded.	All wadeable streams and rivers.	Monitoring should occur according to the protocols found in the *California Salmonid Stream Habitat Restoration Manual, Third Edition* (Flosi et al., 2004).
Large Woody Debris (LWD)	Increasing trend in the volume and frequency of LWD and key pieces of LWD.	Streams and rivers with bankfull channel widths > 1m.	Monitoring should be done according to the protocols found in the *California Salmonid Stream Restoration Manual, Third Edition* by Flosi et al. (2004), or in the Washington State *Method Manual for the Large Woody Debris Survey* (Shuett-Hames et al., 1999).
Pools – Average Residual Pool Depth[2]	Pools >1m in depth, based on minimum residual pool depth.		
Pools – Backwater Pool Distribution	Increasing trend in the number of backwater pools.	Wadeable streams and rivers with channel morphology that supports the development of backwater pools.[102]	Monitoring should occur periodically during the low-flow period and after a heavy winter storm according to the protocols found in the *California Salmonid Stream Restoration Manual, Third Edition* (Flosi et al., 2004).

[100] Adapted from Fitzgerald, 2006.
[101] Adapted from PALCO, 1997.
[102] Steep, v-shaped valleys with little floodplain connection generally do not exhibit this type of habitat and are exempt from this index.

Table 6.2 Instream habitat indicators and target conditions for sediment[100]

Indicator	Target Condition	Applicability	Monitoring/Sampling Notes
Pools – Lateral Scour Pool Distribution	Increasing trend in the number of lateral scour pools.	Wadeable streams and rivers with channel morphology that supports the development of backwater pools.[3]	Monitoring should occur during the low-flow period, after a heavy winter storm, once every five to ten years according to the protocols found in the *California Salmonid Stream Restoration Manual, Third Edition* (Flosi et al., 2004).
Pools – Primary Pool Distribution	Increasing trend in the number of reaches where the length of the reach is composed of ≥ 40% primary pools.	All wadeable streams and rivers.	Monitoring should occur once every five to ten years during the low-flow period and after a heavy winter storm according to the protocols found in the *California Salmonid Stream Restoration Manual, Third Edition* (Flosi et al., 2004). Reported data should include length and depth of pools, and the number of primary pools.
Thalweg Profile	Increasing variation in the thalweg elevation around the mean thalweg profile slope.	Streams and rivers with slopes ≤ 2%.	Monitoring should occur during the low-flow period, after a heavy winter storm, once every five to ten years. The monitored stream segments should be at least 20, but usually 30 to 40, times as long as the average bankfull channel width. Points that should be surveyed include the thalweg, all breaks-in-slope, riffle crests, maximum pool depths, tails of pools, and surface water elevation. Acceptable monitoring protocols include the Channel Geometry Survey of *Water in Environmental Planning* (Dunne and Leopold, 1978).

Prevention of Nuisance Flooding

Accelerated flood frequencies, increased magnitude of flooding events, and the increase in the extent of lateral flood waters as a result of a reduced channel capacity associated with storage of management-related sediment inputs constitute nuisance conditions in portions of the Upper Elk River watershed. Staff proposes bankfull channel conveyance capacity targets based upon historic conditions prior to the onset of exacerbated nuisance flooding conditions. These target conditions will facilitate the evaluation of channel capacity changes as a result of restoration of channel capacity, reduced sediment discharges, and other implementation actions.

The United States Geological Survey (USGS) developed cross-section and streamflow data for the Elk River from 1956 to 1965. These historic measurements were described in the Regional Water Board staff report, *Evaluation of Flooding in Lower Elk River* (Patenaude 2004), and were used to inform the numeric description of the target condition for the bankfull channel capacity as it applies to the Upper Mainstem Elk River. Staff derived estimates of bankfull channel capacity for Lower North Fork and Lower South Fork by scaling the bankfull channel capacity at the former USGS gaging site by the corresponding drainage area. The drainage areas for Upper Mainstem at the former USGS gaging station, for Lower North Fork, and Lower South Fork are 43.13 mi^2, 22.47 mi^2, and 19.46 mi^2, respectively. Table 6.3 provides a statement of the target bankfull channel capacity conditions, the location in which the target condition applies and monitoring/sampling notes.

Table 6.3 Target Condition for Prevention of Nuisance Flooding

Indicator	Target Condition	Applicability	Monitoring/Sampling Notes
Bankfull Channel Capacity	Upper Mainstem = 2,250 cfs Lower North Fork = 1,172 cfs Lower South Fork = 1,015 cfs	Area of stored sediment in depositional reach near confluence of North and South Forks Elk River.	Monitor bankfull discharge. Scale channel capacity by drainage area at measurement location.

Migration

The migration of adult salmonids upstream requires that there be no impassable barriers to their passage from the ocean to their spawning streams. Similarly, once the fry emerge from the gravel, there must be no barrier to the passage of these small fish from the spawning reaches to and among rearing habitats. And finally, once the juveniles are ready to return to the ocean, there must be no barrier to their passage from their rearing reaches to the estuary and out to the ocean. The migration-related numeric target is shown in Table 6.4. This target applies only to management-related barriers, not to natural barriers such as bedrock waterfalls. Human-caused migration barriers include aggraded stream reaches which become too shallow or are dewatered (flow subsurface) during the summer months; undersized or poorly constructed or maintained stream crossings which prevent the migration of anadromous fish past sections of road fill to upstream habitat; or any similar feature. Unless properly designed, winter stream velocities through a culvert can exceed the swimming ability of fish, thus posing a migration barrier.

Table 6.4 Migration Target Condition

Indicator	Target Condition	Applicability	Monitoring/Sampling Notes
Migration barriers on Class I watercourses	Zero human-caused migration barriers by 2018	All Class I watercourses	Reporting across ownership

Conclusion

A suite of numeric target conditions for selected hillslope and instream indicators were established to provide an interpretation of narrative sediment-related water quality objectives. The TMDL analysis reaffirmed that natural and management-related hydrologic factors associated with sediment loads in Upper Elk warrant the consideration of a new water quality objective for watershed hydrology which is based on considerations of stream health and aquatic ecological functioning at the watershed scale. Numeric targets are proposed for each of the hillslope management-related sediment sources identified in the Source Analysis. The suite of hillslope targets were developed that collectively describe hillslope conditions that will conform to Basin Plan water quality objectives and TMDL load allocations. Additionally, numeric targets for the protection of riparian areas and prevention of cumulative watershed effects have been included due to the sensitive nature of the impaired watershed.

Instream numeric targets are included for indicators important to cold water habitat and fish migration. The Upper Elk TMDL is premised on the assumption that conditions supportive of salmonids are supportive of instream water supplies. A proposed instream numeric target for prevention of nuisance flooding is based upon historic channel conveyance capacity measurements by USGS. This target is an important component in the recovery of the beneficial uses and the abatement of nuisance flooding conditions in the watershed.

CHAPTER 7. Implementation Framework for the Upper Elk TMDL

The Upper Elk TMDL presents the technical analyses necessary to support the development of an implementation and monitoring strategy to:

- Goal 1-- Control sediment discharges to the Upper Elk River and its tributaries;
- Goal 2-- Remediate instream-stored sediment originating from historic landuse activities;
- Goal 3-- Achieve ambient water quality objectives;
- Goal 4-- Contain annual winter flows within the historic stream channel and prevent nuisance flooding conditions in the middle reaches;
- Goal 5-- Restore the capacity of pools in the middle reaches to reasonably provide domestic and agricultural supplies of water through surface water intakes; and,
- Goal 6-- Restore the freshwater aquatic habitat conditions necessary for coho, Chinook, steelhead, and coastal cutthroat trout, species of the salmonid family which were historically abundant in the Upper Elk River watershed and are generally indicative of North Coast watershed health.

The implementation framework include a description of general tasks necessary of five different stakeholder groups for the control and monitoring of sediment delivery to the Upper Elk River subbasin, including:

- Regional Water Board
- Humboldt Redwood Company (HRC)
- Green Diamond Resource Company (GDRC)
- Bureau of Land Management (BLM)
- Residents/Water Users

Several key factors were considered by staff in identifying implementation actions necessary to resolve sediment impairment in Upper Elk River watershed including:

- Implementation of sediment control measures by the primary landowners in the Upper Elk River watershed has been ongoing since 1997. These efforts include the inventory, prioritization, treatment, and monitoring of existing sediment sources associated with land management activities. Measures to prevent the creation of new sources continue to evolve.
- Instream deposits of fine sediment in the low gradient stream reaches currently consume the assimilative capacity of Upper Elk River.
- Ongoing sediment deposition continues to impede recovery of beneficial uses of water. Significant hillslope and instream load reductions are necessary to restore the assimilative capacity of the stream system.
- Total sediment delivery to the fluvial system associated with land use activities needs to be reduced by 97-98 percent from contemporary values (2001-2011) in order to meet the sediment load allocation of 120% above natural sediment loads.

- In addition to actions needed to resolve sediment-related threats to fisheries and water supplies, progress is also needed toward recovery of channel and floodplain conditions resulted from the storage of instream deposits from past and ongoing sediment discharges.
- Direct recovery actions in the low gradient stream reaches of the Upper Elk River watershed, combined with sediment load reductions from management-related hillslope sediment sources, are necessary to restore ecosystem functions, abate nuisance flood conditions, attain ambient water quality objectives and recover beneficial uses. The primary objective of any direct recovery action in the lower portion of the Upper Elk River would be to contain bankfull flows (1.5-2 year recurrence interval), while minimizing any adverse effects to upstream and downstream reaches, infrastructure, and land uses. Evaluation of the anticipated effects of sediment reduction measures and direct recovery actions is necessary to inform development of an appropriate and effective approach that integrates actions throughout the affected river channel to inform implementation design, funding, permitting, construction and monitoring.
- The Regional Water Board recognizes the technical, institutional, and monetary challenges that each of the impacted residents and responsible party has faced and may face in designing and implementing measures to reduce fine sediment loads from Upper Elk River and to rehabilitate ecosystem function and restoration of channel capacity in the middle reach of Elk River.
- The implementation framework is constructed to optimize coordination of assessment and treatment of instream deposits in the lower portion of the Upper Elk River among the primary landowners (HRC, BLM, and GDRC), affected private residents, non-profits and assistance organizations, and those with technical expertise in fisheries restoration, hydrodynamics, sediment transport, fluvial geomorphology, and related fields. Such partnerships can ensure in-kind services and cost-shares to achieve favorable positions for receipt of grant funding from state and federal agencies to support implementation actions.
- HRC owns and conducts timber harvest operations on approximately 34.3 mi^2 (76.7%) of the Upper Elk River. Since 2008, HRC has conducted timber harvesting and related activities in the Upper Elk River waterbody according to Waste Discharge Requirements and a Habitat Conservation Plan[103]. Simultaneously, according to Cleanup and Abatement Order requirements[104], HRC has developed and implemented sediment reduction measures that identify, prioritize and treat management-related sediment sources.
- Green Diamond Resource Company (GDRC) owns and/or conducts timber harvesting activities on approximately 5.8 mi^2 (6.6%) of Upper Elk River. Since 2005, GDRC have been operating according to the South Fork Elk River Management Plan which contains watershed-specific elements tailored to the uniquely sensitive geology in the South

[103] Habitat Conservation Plan for Pacific Lumber Company Lands. 1999.
[104] CAO R1-2004-0028 (South Fork and Mainstem Elk River) and R1-2006-0055 (North Fork Elk River)

Fork Elk River. This plan also served as the foundation for the Regional Water Board permitting of timber harvest activities in Upper Elk under Waste Discharge Requirements, according to which GDRC has developed and implemented sediment reduction measures that identify, prioritize and treat management-related sediment sources.

- BLM manages approximately 5.8 mi^2 (13.6%) of Upper Elk River within the Headwaters Forest Reserve according to the Headwaters Forest Management Plan, which was developed with the goal of fisheries recovery and endangered species conservation. Existing management-related sediment discharge sites have been inventoried, prioritized, and are on a schedule for treatment. BLM management activities that have the potential to result in new sediment discharges relate to treatment of controllable sediment discharge sites, Restoration tree thinning which includes hand lopping of trees less than 10 inches in diameter and leaving them onsite, and recreational trail maintenance and use. Pursuant to CWC section 13243, Regional Water Boards may prohibit discharges of waste or types of waste either through WDRs or through waste discharge prohibitions specified in a basin plan. The existing Basin Plan prohibitions for *Logging, Construction and Associated Activities* apply to activities being undertaken by BLM as part of their implementation of the Headwaters Forest Management Plan. In Regional Water Board staff professional opinion, if these activities are implemented in a manner that comply with the existing prohibitions for threatened and actual sediment discharges, in combination with monitoring and reporting, then there is no need for WDR or Waiver coverage of their activities.
- The implementation program framework reflects the consideration and balancing of various relevant factors including, cost, equity, magnitude of impact, degree of management controls in place, feasibility, and probability of success.
- The sediment load allocation is expressed as 120% of the natural sediment load. Therefore, TMDL effectiveness monitoring will focus on measuring human and natural sources of sediment delivery to channels, and instream response to management. This approach provides for the rapid evaluation of the effectiveness of the management measures implemented to reduce sediment loads, and overall progress toward attainment of the TMDL load allocations and the restoration of impaired beneficial uses of water and abatement of nuisance flooding conditions. Furthermore, under this approach, management-related sediment sources are evaluated within the context of the total sediment supply, which is strongly influenced by hydrologic conditions encountered during the subject period.
- There is an existing monitoring network in the Upper Elk River waterbody documenting turbidity, suspended sediment and flow conditions, as well as suspended sediment loads. The network currently tracks suspended sediment loads on a scale that can help to evaluate changes in sediment loads resulting from the combined efforts of the individual primarily landowners in Upper Elk River. Maintenance and potential modification of this network should consider the ability to identify changes in water quality resulting from implementation of watershed recovery and sediment reduction actions.

- The implementation framework is premised on responsible parties performing the monitoring needed to document that the applicable management measures are appropriately implemented. Effectiveness monitoring (e.g., post implementation monitoring of management-related hillslope and instream sediment source) should be designed with appropriate scientific expertise to isolate the effects of individual actions on water quality.
- The TMDL monitoring program should include census of steelhead and salmon populations, focused studies to improve understanding of limiting factors, and other biological information relative to the protection and restoration of cold water fisheries habitat and the protection of salmonid fisheries. Such data will provide additional information to help in the prioritization of management and restoration actions based on estimated costs and environmental benefits, and/or to adaptively update sediment allocations, numeric targets, and/or the schedule for sediment implementation actions.
- Water supplies are best tailored for community-based solution

Table 7.1 summarizes the framework for the implementation program the responsible parties need to develop to achieve the Upper Elk TMDL load allocations.

Table 7.1 Implementation Framework for Upper Elk TMDL.

Responsible Party	**Implementation Actions**
Regional Water Board	• Adopt schedule and milestones for Recovery Assessment and Implementation for load reductions from instream deposits. • Develop regulatory coverage for landowners in the Upper Elk River watershed consistent with the implementation recommendations to achieve the targets and load reductions. • If milestones for load reductions from instream deposits are not achieved, management-related discharges shall not be permitted. • Enrollment of THPs in WWDRs or ownership-WDRs, contingent on the inclusion of adequate discussion and mitigation measures in THPs, relative to cumulative watershed effects
HRC	• Submit revised Report of Waste Discharge consistent with implementation recommendations to achieve targets and load allocations • Participate in: assessment, identification and implementation of management measures, permitting, funding, implementation actions necessary to address instream sediment deposits in the lower portion of the Upper Elk River watershed.
GDRC	• Revise South Fork Elk River Management Plan to be consistent with implementation recommendations to achieve targets and load allocations • Participate in: assessment, identification and implementation of management measures, permitting, funding, implementation actions necessary to address instream sediment deposits in the lower portion of the Upper Elk River watershed.
BLM	• Ensure that activities implemented pursuant to the Headwaters Forest Management Plan comply with the Basin Plan prohibitions and are consistent with implementation recommendations to achieve targets and load allocations.

Responsible Party	**Implementation Actions**
	• Conduct monitoring and reporting of activities to demonstrate compliance with prohibitions. • Participate in: assessment, identification and implementation of management measures, permitting, funding, implementation actions necessary to address instream sediment deposits in the lower portion of the Upper Elk River watershed.
Residents and Other Water Users	• Consider options for alternative water supplies including formation of a district or water company, working with adjacent landowners for easements to alternative water sources, installation of storage to minimize reliance on the river source during summer months, working with public agencies to provide assistance and funding for capital cost • Participate in: assessment, identification and implementation of management measures, permitting, funding, implementation actions necessary to address instream sediment deposits in the lower portion of the Upper Elk River watershed.

Background

On April 17, 2009, Regional Water Board staff announced the start of the required California Environmental Quality Act (CEQA) scoping period for the Elk River Sediment TMDL. On May 20, 2009, Regional Water Board staff held a CEQA scoping meeting in Eureka, California. The purpose of the CEQA scoping meeting was to describe the Regional Water Board staff's proposed approach for development of the Elk River Sediment TMDL. Staff provided a draft framework for TMDL implementation[105] and presented examples of management measures that might reasonably be implemented to comply with a sediment TMDL. Since that time Regional Water Board staff have conducted a number of public workshops, co-sponsored the Elk River Restoration Summit and met numerous times with affected landowners and other stakeholders to discuss the status of the Upper Elk TMDL.

The Upper Elk TMDL and supporting documentation was developed for the uppermost potion of the larger Elk River watershed. The nonpoint sources of sediment identified during development of the TMDL originated from both natural sources and management-induced sediment sources. No point source sediment discharge was identified in the Upper Elk River waterbody.

The primary land use is the management of privately owned industrial timberlands. The threats to water quality from nonpoint source activities in the Upper Elk River are mainly associated with timber harvest, road construction/reconstruction and use, and other factors related to timber harvest operations on private lands. The implementation plan focuses on controlling sediment discharges, and protecting riparian vegetation in accordance with the technical TMDL allocations.

The Upper Elk TMDL establishes the total permissible pollutant load that will achieve water quality standards. This "loading capacity" provides a reference for calculating the

[105] http://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/elk_river/ (as of February 28, 2013)

amount of pollutant reduction needed to bring a waterbody into compliance with water quality standard. The TMDL identifies and assigns allocations to all sources of pollution, including waste load allocations to point sources and load allocations to nonpoint sources (40 CFR § 130 .2(i)). The rationale for the allocations and targets is provided in detail in Chapters 3 through 6 of the Staff Report and in the accompanying technical appendices.

The TMDL program is the primary program responsible for restoring water quality where traditional controls on point sources have proven inadequate to do so. The program is charged with developing implementation plans that consider all sources and causes of impairment, and allocating responsibility for corrective measures that will attain water quality standards. This chapter of the Staff Report presents the framework for an implementation program developed to implement the Upper Elk TMDL load allocation pursuant to Water Code section 13242.

TMDL Implementation Program Framework Regulatory Requirements

In developing the framework for the implementation program, the Regional Water Board staff considered the nature of the discharges in the Upper Elk River watershed as well as existing efforts being implemented to protect and restore the beneficial uses of water and abate nuisance flooding conditions. The implementation framework proposes discrete and identifiable implementation actions needed to bring the waterbody into compliance. The framework also identifies the parties responsible for implementing those measures. It also describes the Regional Water Board's current regulatory strategy for controlling pollutant sources and recommends improvements to existing regulatory controls. The plan sets time schedules by which the responsible parties will implement their compliance measures and also includes a monitoring plan to track progress towards compliance.

The progress of the implementation plan will be tracked through a coordinated monitoring effort to establish water quality trends as well as through submittal of required monitoring and reporting programs. The Regional Water Board will make any necessary revisions to the implementation plan as needed to achieve water quality standards within a reasonable timeframe.

Implementation actions taken to achieve load allocations must be consistent with the *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program* (NPS Policy). The NPS Policy requires that all current and proposed nonpoint source discharges must be regulated under waste discharge requirements (WDRs), waivers of WDRs, a Basin Plan prohibition, or some combination of these tools. If the source is currently unregulated, or the current permits, waivers and/or prohibitions are not sufficient to attain the TMDL, a means to comply with the NPS Policy must be proposed as part of the implementation plan. The Regional Water Board may also certify existing pollution control programs as sufficient to implement the Upper Elk TMDL if it can make the following findings:

1. The implementing program is consistent with the assumptions and requirements of the TMDL;
2. Sufficient mechanisms exist to provide reasonable assurances that the program will address the impairment in a reasonable period of time; and
3. Sufficient mechanisms exist to ensure that the program will be enforced, or that the Regional Water Board has sufficient confidence that the program will be implemented such that further regulatory action would be unnecessary and redundant.

All five of the key elements presented in the NPS Policy are reflected in the proposed framework for the Upper Elk TMDL Implementation Program. The NPS Policy includes goals to track, monitor, assess and report program activities; target specific program activities; coordinate with public and private partners; provide financial and technical assistance and education; and implement management measures. These goals are designed to reduce and prevent nonpoint source pollution.
USEPA[106] recommends that TMDL implementation plans include each of the following elements:

- List of actions needed to achieve load allocations and numeric targets specified by the TMDL, and a schedule, including interim milestones for implementation of those actions

- Reasonable assurances (provided by the state water quality agency) that implementation actions specified in the plan will occur. These include being able to demonstrate that the specified actions will be effective, and that adequate resources will be available to successfully execute the program.

- A description of the legal authority (of local, state, and/or federal government agencies) under which the necessary actions will or could be required.

- Monitoring or modeling plan, including milestones for measuring progress, in achieving water quality standards.

- Adaptive management plan that includes a schedule for iterative update(s) of the TMDL in response to monitoring or modeling results, and/or other information that is new and relevant to the determination of whether water quality standards have been achieved.

- Estimated amount of time required to restore clean water including basis for estimate.

[106] USEPA, 1999.

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